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Canada. Geodetic Service

DEPARTMENT OF THE INTERIOR, CANADA

HON. CHARLES STEWART, Minister — W. W. CORY, Deputy Minister

GEODETIC SURVEY OF CANADA

NOEL OGILVIE, Director

ANNUAL REPORT

OF THE DIRECTOR

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1923

1922/23

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1924

Triangulation Towers

From these towers other triangulation stations can be seen, and from them the measures of the angles of the triangulation nets are made. They are of sufficient height to overcome local timber or ridges between triangulation stations.

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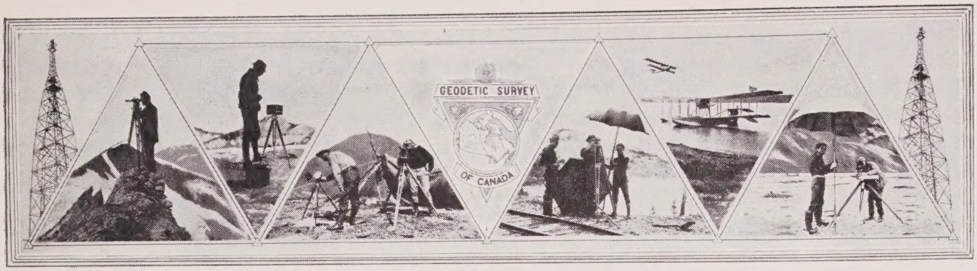

REPORT OF DIRECTOR OF THE

GEODETIC SURVEY OF CANADA

Sir,—I have the honour to submit my sixth annual report as Director of the Geodetic Survey of Canada, for the fiscal year ending March 31, 1923.

RÉSUMÉ OF OPERATIONS

The following table shows the districts in which field work was carried on:—

Province	District	Operations
Nova Scotia	Bay of Fundy	Precise Levelling.
	Cape Breton Island and Magdalen islands	Primary Triangulation
Prince Edward Island	Eastern End	Primary Triangulation
New Brunswick	St. John river	Precise Levelling
	Peticodiac River	Precise Levelling
New Brunswick and Quebec	Bay of Chaleur	Primary Triangulation
Quebec	Gulf of St. Lawrence	Primary Triangulation
	Saguenay River	Secondary Triangulation
	City of Quebec	Secondary Triangulation
	City of Quebec	Precise Levelling
Quebec and Ontario	Ottawa River	Primary Triangulation
Ontario		Reference Monument Inspection
	City of London	City Mapping
	T. and N.O. Railway	Precise Levelling
	Canadian National Railway (Transcontinental)	Precise Levelling
	City of Hamilton	Precise Levelling
	Port Arthur Harbour	Secondary Triangulation
Ontario and Manitoba	English and Winnipeg Rivers	Precise Levelling
Manitoba	49th Parallel	Primary Triangulation
Saskatchewan	49th Parallel	Primary Triangulation
	Alsask Vicinity	Precise levelling
Alberta	Wetaskiwin Vicinity	Precise Levelling
Alberta and British Columbia	Yellowhead Pass	Secondary Triangulation
		Base Line Measurement
British Columbia	Vancouver Island	Base Line Measurement
	Vancouver Island	Geodetic Astronomy
	Vancouver Island	Secondary Triangulation
	Southern British Columbia	Precise Levelling
	Northern British Columbia Coast	Primary Triangulation

In the above list two points are to be noted:—

1. Operations in more than one district were in some cases carried on by the one party, where the amount of work in one district did not occupy the whole season. For example, the precise levelling in the districts described as bay of Fundy, St. John river and Peticodiac river, was all done by the one party. At least five similar cases occur in the above list.

2. Operations in one district were in some cases accomplished by several parties. For example, the name Primary Triangulation comprises the following operations: reconnaissance, tower building, station preparation, direction measurement and accessory operations. In some regions all of the above operations were carried out in one district, as in Cape Breton or the gulf of St. Lawrence. In other places only one of these operations was carried on, as in the Ottawa River district, where only reconnaissance was proceeded with in 1922. Similarly, the precise levelling in the English and Winnipeg River district was carried on by three parties. This situation occurs at eight places in the above list.

Precise Levelling

The amount of levelling accomplised in the fiscal year 1922-23 was 1,306 miles and 498 bench-marks were established. Adding these amounts to what has been done in the past, the Survey's precise level net now consists of 16,322 miles and contains 5,042 bench-marks.

In order to meet the requirements of the Tidal and Current Survey a party went to the Maritime Provinces in the spring and ran some lines at the head of the bay of Fundy and up the valley of the St. John river. Requests for additional precise levelling control were also received from the cities of Hamilton, Ont., and Quebec, Que., and were complied with in full, the work being carried out under the usual co-operative plan by which the Geodetic Survey furnishes the engineer to carry on the levelling and provides the necessary instruments, the city bearing all other expenses.

Triangulation

The weather during the summer of 1922 was probably the most unfavourable for primary triangulation for a number of years, in all sections of the country except on the northern British Columbia coast. In the Magdalen Island area long lines, fog and haze caused one of the poorest seasons on record. Various conditions contributed to a medium season on the gulf of St. Lawrence. On the 49th parallel in Saskatchewan unprecedented smoke caused great delay for the party measuring horizontal directions. The same condition is understood to have delayed United States parties working southwest in Idaho. On the southern British Columbia coast, long sights were impossible until August 15, when the smoke was cleared by rains. The notable exception was on the northern British Columbia coast, where fog and rain are the rule (at Swanson Bay the mean monthly precipitation from May to September is about 8½ inches). The dry weather which in other parts of the country conduced to forest fires, in this northern area led to an absence of the usual fog and rain and produced unusually good conditions for triangulation.

Nova Scotia.—Cape Breton island and the Magdalen islands (part of Quebec) were the scene of triangulation operations in this province. Reconnaissance for the selection of stations was carried on northward from Sydney, N.S., a scheme as shown on page 49 being located to cape North, St. Paul island and Newfoundland. Towers have been built and stations prepared over this same area.

Northern Cape Breton island is one of the most difficult areas for triangulation that has been encountered. The land rises abruptly from the water to a very flat plateau cut by the cañon-like valleys of rivers. The interior is difficult of access. The timber is short except in the valleys, and it was, hence, difficult to procure and transport timber for towers. In some cases trails had to be cut for several miles to give access to the stations.

A triangulation connection with cape Ray, Newfoundland, was found feasible, and the reconnaissance for selection of stations was completed. This connection will provide a basis for any future triangulation which may be carried

on by Newfoundland and will be of immediate use in revising charts of New foundland based on the astronomical position of cape Ray.

Triangulation connection with the Magdalen islands was completed during 1922. Hydrographic surveys of this area are in progress so its accurate connection with the adjoining mainland was a matter of immediate importance. In this connection one station was reoccupied on Prince Edward Island.

For a plan of the triangulation in these areas see the sketch on page 49.

New Brunswick.—The only triangulation operations carried on during 1922 were on the bay of Chaleur, where part of a season was spent by a reconnaissance party selecting stations for connecting the triangulation net in Gaspé with that of the eastern New Brunswick coast. For sketch see page 46.

Quebec.—Triangulation operations were carried on in two areas in Quebec, the gulf of St. Lawrence and the Saguenay river areas.

Operations on the gulf of St. Lawrence were carried on by one reconnaissance, one tower building and two direction measurement parties with their subsidiary lightkeeping parties. All of these parties were interdependent and were co-ordinated by one engineer in charge, who employed the C.G.S. "Gulnare" to transport the various units from place to place.

One feature of these operations was successfully concluded, which had been the cause of concern for three years. Several long lines across the gulf of St. Lawrence passed very close to the water and it was known from the reconnaissance investigations that under normal conditions of refraction the lines would be closed. The two lines regarding which there was the greatest concern were the lines Cloridorme to Thunder and Cloridorme to Sheldrake, each about 80 miles long, with terminal heights of about 1,500 feet at the Cloridorme end and 250 feet at the other ends. (See sketch on page 49 of the Annual Report of the Superintendent of the Geodetic Survey of Canada for the year ending March 31, 1922). Only an abnormal coefficient of refraction opened the lines. Cloridorme was occupied in 1922, the other ends having been occupied in 1921. On several clear nights the lights were invisible; the coefficient of refraction was measured on a lighthouse over 50 miles away in approximately the same direction and was found to be about normal. Finally a night came on which it was found to be abnormally large, the lights were visible and the required angular measurements completed.* With these measurements finished the greatest cause of difficulty and delay in this area has been surmounted. Six other stations from which comparatively long lines radiate (50 to 60 miles) remain to be occupied, after which the average length of line will be less than 30 miles.

In the Saguenay River area, field operations consisted in a revision of reconnaissance of the primary net from Tadoussac to Chicoutimi, together with secondary triangulation from Chicoutimi to and around lake St. John. The physical difficulties of the lower 60 miles of the Saguenay made it advisable to cover that section with as few stations as possible; accordingly, larger figures were selected. Several blocked lines made a revision of this triangulation necessary in the fall of 1922, so that the angular measurements had to be delayed until 1923. The secondary scheme selected and completed above Chicoutimi is shown on the sketch on page 40. The parts consisted of units for the reconnaissance, station preparation and tower building, and angular measurements. Astronomical stations at Chicoutimi and Roberval, as well as a great many church spires and land survey corners were tied in, so that the geographical value of the net will be large to provincial authorities. Positions cannot be obtained until the lower Saguenay work is completed in the spring of 1923.

A scheme of triangulation was laid down in the fall of 1922 covering the city of Quebec and vicinity under the regular co-operative arrangements applicable to such cases, that is, this Survey provided the engineer and the necessary

* Considerable data has been gathered regarding coefficients of refraction, as a result of systematic observations on the gulf of St. Lawrence. These will be published shortly.

instruments while the city paid all other expenses. A considerable number of Canadian cities have availed themselves of similar facilities for obtaining an accurate framework on which to base city mapping. The arrangement embraces precise levelling as well as triangulation nets.

It may be questioned whether this Survey should even provide the engineer for such work, but it will be realized that the points so determined in the cities are frequently used by various federal departments in connection with smaller surveys for special purposes. In addition, during the course of the work the positions of a considerable number of additional points outside the city, such as church spires, lighthouses, etc., are accurately determined, which are very useful for geographic purposes to whoever requires them. Hence, at a trivial cost, the federal government is conferring a favour on the city by helping with work which the city staff is insufficiently equipped to provide for itself, and at the same time is obtaining considerable information which is useful to federal departments and to others.

A plan showing the distribution of stations in the city is shown on page 36.

Ontario.—A reconnaissance party started work at Ottawa in the spring of 1922 for the selection of stations of a triangulation net up the Ottawa river This is a net of great importance, as a great deal of triangulation in Northern Ontario and Quebec will eventually depend on it for its connection with the triangulation of the south and with the North American Datum.

Reference to Map 2, facing page 18 of the annual report for the fiscal year ending March 31, 1922, shows that this net will eventually be extended up the Temiskaming and Northern Ontario railway to Cochrane and James bay, with branches towards Sudbury, Sault Ste. Marie and Port Arthur, and east and west along the Canadian National railway (Transcontinental), with connections at numerous points with the interprovincial boundary between Quebec and Ontario.

The total distance covered was approximately 100 miles, stations being selected as far as Des Joachim rapids.

An inspection party was engaged during the season in going over all the triangulation stations in Ontario to see that all triangulation station marks were preserved and to mend any reference monuments which might have become defaced or broken. It is highly important that the permanency of the triangulation stations be preserved for future generations, so periodic inspections are advisable. Not only is permanence essential; the station must be capable of being found with reasonable ease by engineers who are not used to looking for them, and while inconspicuousness aids permanency, it is the aim to secure reasonable conspicuousness in addition to permanence. For this reason improvements in the methods of marking triangulation stations are adopted from time to time, and as opportunity permits stations are re-marked. During such inspections descriptions of stations are revised, obsolete material is deleted and new data added.

A secondary scheme of triangulation was laid down and completed covering the harbours of Fort William and Port Arthur, at the request of the Public Works Department. Discrepancies in existing surveys and the increasing value of waterfront property made it advisable that a series of accurately determined points be established as a basis for further development of the harbour. A base line was measured with invar tapes on one of the breakwaters to control the lengths of lines between triangulation stations. The scheme was connected to a primary triangulation station on mount McKay and by this means the geographic positions of the stations and the azimuths of all lines were established. For fuller details see page 32.

Manitoba and Saskatchewan.—Geodetic work in these two provinces will be considered as a unit, as four interdependent parties were working on various stages of same scheme. This consists of a net of triangulation from lake of

the Woods to the Pacific ocean which is being carried on in co-operation with the United States Coast and Geodetic Survey along the 49th parallel international boundary. Of this net the Director of the United States Survey says:* "This is one of the most important and extensive pieces of co-operation geodetic work in surveying and mapping between two countries of which there is record." The share of the Geodetic Survey of Canada in this work is the section from the 109th meridian to lake of the Woods, or roughly along the southern boundaries of Saskatchewan and Manitoba, a distance of about 625 miles.

During 1921 two reconnaissance parties had selected the stations of part of this net. In 1922 one reconnaissance party was continued and a tower-building party, a station preparation party and direction measurement party were added.

In the western Saskatchewan part of the net few towers were required, and in this section a station preparation party operated, building the concrete piers which mark the stations. This operation is generally done by the direction measurement party, but in that section sand, gravel and cement for the concrete are so scarce (the average haul for gravel was 30 miles) that a special party was required for this work.

On the direction measurement party an innovation was introduced with great success, by the use of electric signal lamps equipped with time switches. †This plan reduced the number of men required, as only one first-class light-keeper was used in place of six who would otherwise have been needed. The saving was about $20 per day, and the operation party was centralized and simplified.

Interesting data regarding the work in this area is given on page 30.

British Columbia.—Triangulation operations were carried on in three sections of the province. The most easterly was a secondary scheme which was started along the British Columbia-Alberta boundary northward from the Yellowhead pass to the last intersection of the continental divide with the 120th meridian. The reconnaissance for selection of stations for about three-quarters of the total air line distance of over one hundred miles was completed in a short season. The programme is expected to cover two years more. A base line was measured on the ice of Yellowhead lake during January and February, 1923, to control the lengths of this scheme.

On Vancouver island a secondary expansion of the primary triangulation net along the coast was projected to furnish primary control for a topographic party of the Geological Survey which was operating in the region of the south of Comox. Owing to the dense smoke the angular measurements of this scheme could not be made until August, 1922.

On the northern British Columbia coast the main net along the coast was continued and unusually good weather resulted in very satisfactory progress being made. With one more good season it is possible that a connection will be made between the net which was laid down in the general vicinity of Prince Rupert with that which has been carried up from the south, when the former net, together with United States triangulation along the southeastern Alaska coast will be solidly linked with the North American Datum. The party was moved south in September to make the angular measurements necessary to connect to the main net a base line which was measured near Oyster bay, Vancouver island.

Base Lines

Two base lines were measured during the fiscal year, one on Vancouver island near Oyster bay, in connection with the primary triangulation net along

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* See Annual Report of the Director of the United States Coast and Geodetic Survey for the fiscal year ending June 30, 1922, p. 54.

† See pages 11 and 28 for further description.

the coast, and the other on the ice of Yellowhead lake. The latter base line controls the lengths of a secondary triangulation net along the summit of the Rocky mountains, used by the Interprovincial Boundary Commission.

Features of each base line are worth mentioning. The Oyster Bay base line was located, for part of its length, along a beach which at high tide was covered with water, so that the posts which supported the invar tapes were submerged and the measuring had to be done at low water. No trouble was experienced due to this condition. Another feature which the base location made necessary, was a deflection of about 10 degrees near the middle of the base. The greatest care was exercised in the measurement of this deflection angle and no appreciable decrease in accuracy resulted from this occurrence.

The Yellowhead Lake base line was located along the centre of the lake and the measurements were made on the ice; no other suitable location was available. Holes were made in the ice with an ice chisel and the posts for supporting the tape were frozen in. The line was divided into sections, the ends of the sections lying on points of the shore and being marked by concrete piers. The lengths of the sections were varied to suit topographic conditions, it being attempted to have no section longer than 1½ to 2 kilometres, so that the measurements of each section could be completed at one time. The disadvantages of measuring base lines in this manner are: uncertainty that the coefficient of expansion of the tapes holds good for temperatures around 0° Fahrenheit; possibility of greater friction in the measuring apparatus at that temperaure; loss of time due to the shorter length of daylight and to delays unavoidable when working in low temperatures. These disadvantages are being investigated to see if they can be overcome. The advantages are several—feasibility of selecting base lines in country where a base line on land would be impossible; improvement in the geometrical figures of base nets, due to the greater flexibility in the location of the base line; absence of labour in clearing the base line of timber.

It is believed that this method of measuring base lines on the ice has good possibilities for primary triangulation, if proper precautions are observed.

For further information see page 51.

Geodetic Astronomy

Two Laplace stations (coincident triangulation longitude and azimuth) were occupied during the fiscal year 1922-23, both in the British Columbia triangulation at Little Mountain near Vancouver and Cape Lazo on the east coast of Vancouver island. These two Laplace points, along with Klucksiwi at the north end of Vancouver island, give three controls for the azimuth of the British Columbia triangulation net. The longitude of Cape Lazo was previously determined in 1915 with Vancouver as a base point, but in order to obtain an additional loop for the Canadian longitude net, advantage was taken of the presence of an astronomic party in British Columbia to determine the longitude from Ottawa. In connection with the longitudes on the North American continent it is desirable that the Canadian, United States and Mexican longitudes be connected in one longitude net. To secure this end it may be necessary to make several determinations of differences of longitude between United States and Canadian stations and readjust the longitude nets of the two countries.

City Mapping

The experimental work on city mapping was continued under the contract with the city of London, Ont. Enough detailed mapping has been finished to date to complete a map of about four-tenths of the area within the city limits. Changes in the organization of the field work have again made a substantial reduction in the cost per acre.

During January, publication No. 9, entitled, "The Making of Topographical Maps of Cities and Towns, the First Step in Town Planning," was issued. The large numbers of letters of appreciation which have been received show that the need of large scale city maps is being felt both in Canada and the United States.

ELECTRIC SIGNAL LAMPS AND AUTOMATIC TIME SWITCHES

The Geodetic Survey has been able to show a substantial economy in the operation of one class of its parties by the introduction of automatic time switches in connection with electric signal lamps employed in triangulation. Where this apparatus can be used the number of employees on the angular measurement parties may be reduced by from four to seven men with a corresponding saving.

The angular measurements of the triangulation of the Geodetic Survey of Canada are made at night, as this practice proves more economical and accurate than making them in the day time. Instead of pointing on targets, as one may in daytime, it is necessary to point on lights, and various types of lights have been used from time to time. First railway signal oil lamps with condensing lenses were used; later acetylene lamps, somewhat similar to the old style automobile headlight—but much larger—were found to be a great improvement. Each lamp is tended by one, or in some districts two, lightkeepers, from five to eight lamps being necessary for each party.

As the triangulation lines are long—often 40, at times 100 miles—and as haze or fog often makes it impossible to see the lights described above at these distances, it has been the constant aim to increase the strength of the lamps, and hence, increase the number of nights on which observations can be made.

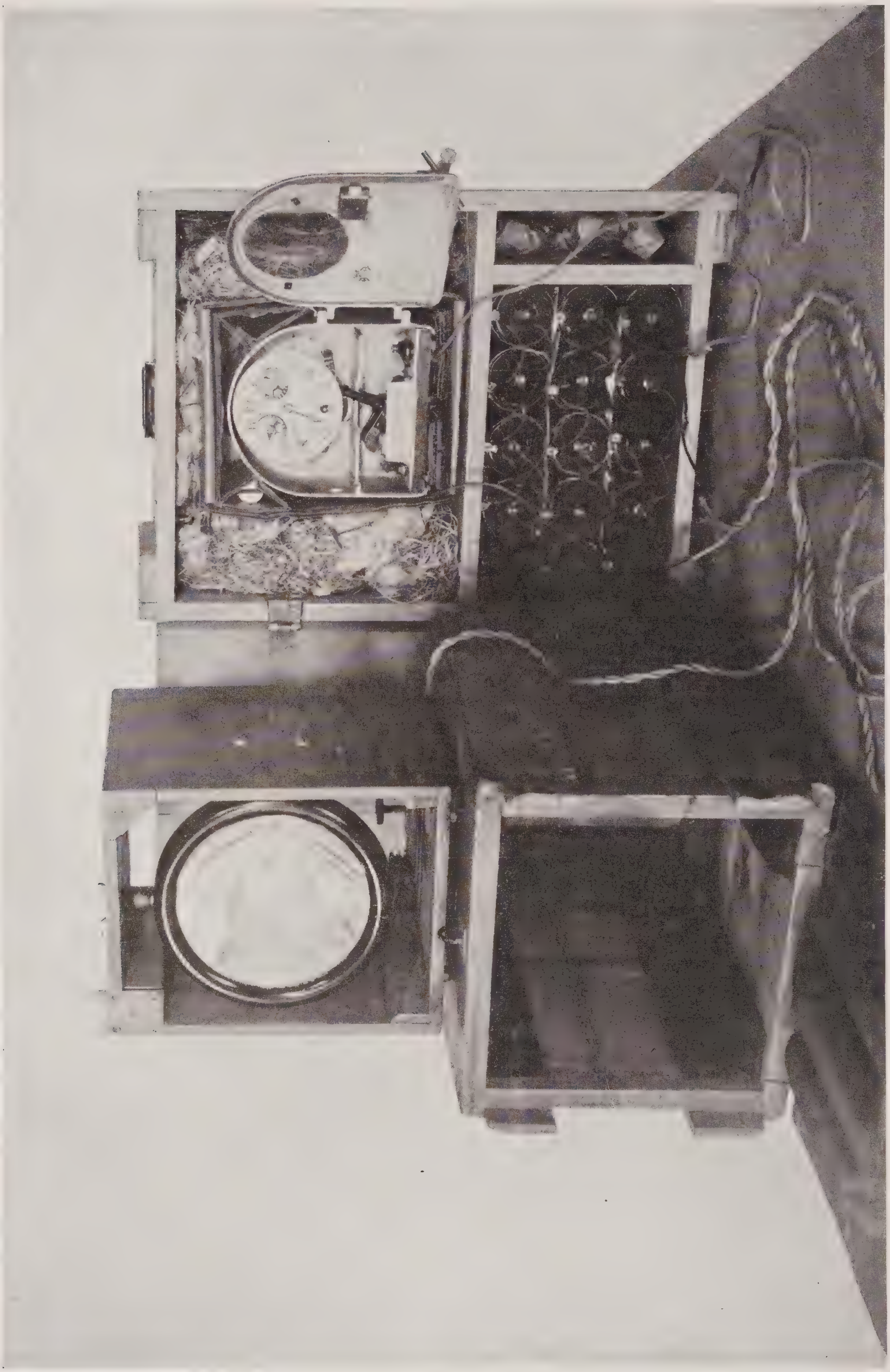
In 1920 electric lamps were introduced. Automobile headlights were specially mounted and proved much stronger and more economical, both in initial cost and in operation, than the acetylene lamps. Two sizes of special miniature bulbs are used (depending on the length of line), while current is provided either by dry cells or storage batteries. The old style acetylene lamp has also been adapted to use electric bulbs, and this change has greatly increased its efficiency.

The latest improvement to the electric lamp makes possible an important saving in operation. A time switch is placed in the circuit, and, when the lamp has been properly lined, the clock wound and the "on" and "off" dials set, the switch will automatically turn the light on and off at pre-arranged hours. In this way several lightkeepers may be dispensed with, only one lightkeeper with a light motor truck being attached to the party to move the lights when necessary and to wind the clocks once a week.

It is to be noted that this equipment will, in general, be found feasible only where transportation is easy and the triangulation stations comparatively close together. Its use would be limited in a mountainous country for example, on account of the time which would be lost moving all the lamps, but even in such cases a saving is possible by employing only a minimum number of men and using the automatic switches where more men would be occasionally required.

Several other operations of the Geodetic Survey of Canada with which this equipment can be economically used are anticipated, and it is felt that a large step forward has been made in the economical handling of triangulation operations.

In this, as in other improvements, the United States Coast and Geodetic Survey and the Geodetic Survey of Canada are working in close harmony, the suggestions of each organization being freely offered and accepted.



Electric signal Lamp with Automatic Time Switch.
This equipment automatically turns the electric lamp on and off at predetermined hours, and eliminates lightkeepers where transportation is quick and the stations fairly close together (see text).

THE VALUE OF GEODETIC CONTROL IN CITY SURVEY WORK

The standardizing of methods and practices in city survey work is a most desirable attainment from the points of view both of accuracy and economy, and it is easily shown that geodetic control simplifies the attaining of this feature. In view of rapidly changing personnel of the engineering staffs of city departments such a standardization makes possible the keeping of records in such shape that they may be easily referred to and understood by any engineer joining the staff.

Geodetic control is based on the primary triangulation and precise level nets of the country and its availability and permanence ensures accuracy of work, economy of time and a great saving of money to the taxpayer.

The permanency of survey marks is of the utmost importance and they should be made of such material and placed in position in such a manner that will insure relative permanency. However, careless excavations by contractors or street foremen will continue to disturb the most permanently placed marks unless their work is carefully supervised by the engineer in charge. Disturbed marks whose positions have been determined in reference to a geodetic datum, can always be replaced accurately, because there is but one point which is the intersection of any given meridian and parallel on the geodetic datum, and that point has for reference marks all the other permanent survey points in the city —or for that matter in the country—whose positions are on the same datum.

Thus, if any points that are fixed with the same accuracy and based upon the present triangulation and precise level systems in the cities of London, Montreal, Toronto, Quebec, etc., should be lost, they can be accurately re-established at any time, because the triangulation of those cities is based upon the "North American Datum" which is the datum of Canada, United States and Mexico.

PUBLICATIONS

It has been the practice of this survey to issue publications containing data made available by completed operations, for the use of engineers, surveyors and surveying branches of the Federal and Provincial Governments.

Copies of these publications are distributed by means of permanent mailing lists which are carefully revised from notification cards. Copies of any publication may be obtained by applying to the Director of the Geodetic Survey of Canada. No charge is made.

A list of publications now available will be found at the end of this report.

OPERATIONS OF THE SURVEY

General Report on Precise Levelling in 1922-23

(F. B. Reid, Supervisor of Levelling)

Five precise levelling parties were in the field in the summer of 1922, in charge of Messrs. McMillan, Dalton, Sinclair, Raley and Smith, respectively. The first of these was engaged in the Maritime provinces, the second and third in northern Ontario, the forth in the Prairie Provinces and the fifth in British Columbia. In the winter of 1922-23 three parties were in the field in Manitoba and northern Ontario.

The summer levelling operations included special work in two cities, Hamilton, Ont., and Quebec, Que.

In Hamilton the city engineer installed thirty-seven bench-marks so distributed as to furnish convenient bases for local levelling operations in any

quarter of the city; the Geodetic Survey, at the request of the city, undertook the work of connecting these bench-marks by precise levelling. The bench-marks, it may be remarked, consisted of a section of two-inch gas pipe 6 feet 6 inches in length set vertically and screwed into a cast-iron base 5 inches in diameter; the bench-marks were placed either in sidewalks or roadways and were finished at the upper end with a four-inch brass cap set slightly below the surface of the sidewalk or roadway and protected by means of an ordinary water service valve box cover, the elevation of the bench-mark being taken on the flattened top of the brass cap. The excavation for the gas pipe was made with a post hole auger and the space around the pipe packed in with concrete.

Under the arrangement entered into with the city of Hamilton no charge was made for the services of the engineer carrying out the levelling, nor for the use of the instruments required. The Geodetic Survey also performed the necessary office work in connection with compiling and adjusting the field notes. The subsistence of the engineer, the wages and subsistence of his assistant and the travelling and incidental expenses were charged to the city—these amounting in all to $250.50. In addition the city bore the cost of establishing the bench-marks and supplied three labourers to act as rodmen and assist in other capacities.

One of the Survey's precise level lines already passed through the city (along the Canadian National railway) so a proper datum for the levelling was readily available; the work was planned so that most of the new bench-marks were included in self closing loops; one of these loops extended up the "Mountain" and down again to the lower portion of the city. 4·37 miles of duplicate (forward and backward) levelling was run and 22·67 miles of single levelling loops, equivalent to a total of 15·7 miles of standard duplicate levelling. The Hamilton work was carried out by Mr. Dalton between May 23 and June 7.

A request for additional precise levelling control in the city of Quebec having been received, Mr. Sinclair proceeded to that city on October 22 and established and connected up a series of twenty-seven bench-marks which were so located that, in conjunction which those previously established, complete levelling control was furnished to the city. The new bench-marks consisted of bronze tablets instead of the standard copper bolts; these were for the most part set horizontally in the walls of churches and other public buildings.

The precise levelling in the vicinity of Quebec in 1919 furnished an excellent foundation for the new levelling; a loop line of duplicate levelling having at that time been extended along the river shore and around the city through lower town, the new levelling was easily built up from it in the form of cross lines and loops—partly of single and partly double running.

The levelling in Quebec was financed in much the same manner as in Hamilton, the city bearing all expense, except the salary of the engineer in charge and the cost of the office work and supervision. The amount charged to the city was about $200, this sum covering the subsistence of the engineer, the wages and subsistence of his assistant and the travelling and incidental expenses. The bronze tablets were supplied by the Geodetic Survey, but the city furnished a man to install the same and also furnished such assistance as was required in the way of rodmen for the time the work was in progress—a little less than two weeks.

The mileage run by each engineer is shown in the following table, also the percentage of relevelling, the number of standard bench-mark piers built and the total number of bench-marks established, including piers:—

Engineer in Charge	Mileage levelled	Percentage relevelled	Piers built	Tota B. Ms. Estab- lished
SUMMER 1922				
D. McMillan	124	16	17	58
G. F. Dalton	225	7	11	109
G. E. B. Sinclair	221	7	16	115
G. S. Raley	176	23	37	53
N. H. Smith	196	15	17	98
WINTER 1922-23				
G. E. B. Sinclair	115	27	0	24
G. S. Raley	112	35	0	16
W. J. Lowndes	137	23	0	25
	1,306		98	498

The above mileages represent new levelling only; any rerunning done in starting from or closing on old lines of levels is not included. In reckoning the number of bench-marks those in Hamilton (thirty-seven in number) have not been included as these were installed by the city and are of an entirely different type to the standard bench-marks of the Geodetic Survey; nor are they designated with the name or initials of the survey. The Quebec city bench-marks are included, however, these being bronze tablets inscribed with the name of the Geodetic Survey and installed under the direction of an officer of the Survey.

The following is a summary of the lines levelled in 1922:—

Line	On Railway	Off Railway	Total
SUMMER 1922	miles	miles	miles
Kennetcook to Burntcoat, N.S	0·0	11·7	11·7
Maccan to Joggins, N.S	11·5	1·2	12·7
Salisbury to Albert, N.B	44·7	5·2	49·9
St. John to Gagetown, N.B	50·1	0·1	50·2
Hamilton City lines	0·0	15·7	15·7
Latchford to Cochrane, Ont., with branches	226·4	3·6	230·0
Kabina to Lowbush, Ont	187·2	0·6	187·8
Quebec City Lines	0·0	12·0	12·0
Alsask, Sask., to Compeer, Alta	6·1	36·8	42·9
Kerrobert to Unity, Sask	92·8	1·9	94·7
Camrose to Wetaskiwin, Alta	36·9	1·4	38·3
Revelstoke to Arrowhead, B.C	27·4	0·0	27·4
Sicamous to Okanagan Landing, B.C	50·8	0·0	50·8
Spence Bridge to Brodie, B.C	65·5	0·0	65·5
Mission to Hope, B.C	52·7	0·0	52·7
WINTER 1922-23			
Winnipeg river	0·0	177·7	177·7
English river	0·0	185·8	185·8
	852·1	453·7	1,305·8

Previous to 1922, 15,016 miles of levelling had been accomplished; the total to date is, therefore, 16,322 miles.

The number of bench-marks established this year was 498 which brings the total number at the present time to 5,042—not including those of other organizations which have been connected with our levelling.

The mileage of the levelling since the beginning of the work is distributed among the provinces as follows:—

Province	Previous to 1922	1922	Total
	miles	miles	miles
Ontario	4,588	682	5,270
British Columbia	2,068	196	2,264
Saskatchewan	1,950	138	2,088
Quebec	1,776	12	1,788
Alberta	1,481	38	1,519
Manitoba	1,037	116	1,153
New Brunswick	864	100	964
Nova Scotia	705	24	729
Yukon Territory	458	0	458
Minnesota, U.S.A	89	0	89
	15,016	1,306	16,322

It is distributed among the railways as follows:—

Railway	Previous to 1922	1922	Total
	miles	miles	miles
Canadian National	7,267	282	7,549
Canadian Pacific	5,558	332	5,890
Timiskaming and Northern Ontario	94	226	320
Great Northern	230	0	230
Algoma Central	219	0	219
Dominion Atlantic	146	0	146
Quebec Central	109	0	109
White Pass and Yukon	91	0	91
Temiscouata	82	0	82
Ottawa and New York	55	0	55
Pere Marquette	55	0	55
Maine Central	36	0	36
Boston and Maine	34	0	34
Napierville Junction	28	0	28
British Columbia Electric	28	0	28
Quebec Railway Light and Power Co	25	0	25
Maritime Coal, Railway and Power Co	0	12	12
Pacific Great Eastern	9	0	9
Michigan Central	3	0	3
London and Port Stanley	2	0	2
Highways and cross-country levels	945	454	1,399
Total	15,016	1,306	16,322

Winter Levelling, 1922-23.—During the winter of 1922-23, the Geodetic Survey undertook the extension of a line of precise levels along the Winnipeg river from Kenora, Ont., to the mouth of the river at Fort Alexander, Man., and along the English river from its confluence with the Winnipeg river to lac Seul and Pelican falls, Ontario.

While it is contrary to the usual practice to undertake precise levelling in the depth of winter, in this particular case a large saving of time and expenditure resulted; had the work to be carried out during the summer season routes for

the levels would in most cases have had to be chopped through the bush and around every lake and bay encountered—water transfers across the small lakes affected by the current not being sufficiently reliable.

The trunk lines of precise levels run some years ago by the Geodetic Survey along the railways in this district furnished an excellent base for the new levelling—Kenora on the Canadian Pacific railway and Minaki, Favel and Hudson on the main line of the Canadian National railway being control points to which the levelling was connected. The general programme of field operations was for one party to start at the mouth of the Winnipeg river and work up its course to the confluence with the English river near Whitedog island, a second party started at Kenora and followed the Winnipeg river down to this point and then turned up the English river and continued till it met the third party which started at Hudson and worked down the river. By this arrangement the amounts of work assigned to the parties were approximately equal.

Precise Levelling in Nova Scotia and New Brunswick

(D. McMillan)

Beginning on May 1, a line of precise levels was run from Kennetcook, N.S., along Noel road to Noel village; thence westerly to Burntcoat Head lighthouse, terminating upon a bench-mark of the Tidal Survey. Four bench-marks were placed along the road between Kennetcook and Burntcoat Head, a distance of 12 miles. Bench-marks on the Dominion Atlantic railway near Kennetcook, established in 1914, were examined and tested by relevelling and were found to have held their elevations unchanged.

On May 17 the party moved to Maccan, N.S., and, after testing the bench-marks formerly placed in that neighbourhood, ran a line along the Maritime Coal, Railway and Power Company's railway to Joggins, connecting there with a bench-mark of the Tidal and Current Survey.

The next work undertaken was a line along the Canadian National Railway branch from Salisbury to Albert, N.B. From Cape station on this line a branch was run to a Tidal Survey bench-mark at Hopewell Cape village. Connections were also made with two bench-marks of the Geological Survey of Canada situate near Stoney Creek.

On completion of the Albert subdivision, the party moved to St. John and commenced a line north from that city along the St. John river; tying in at intervals with elevation marks of the Public Works Department. On August 7, the work was discontinued and the party disbanded at Gagetown.

In the course of the season's operations fifty-eight new bench-marks were established around the head of the bay of Fundy and along the St. John river.

Precise Levelling in the City of Hamilton and Northern Ontario

(G. F. Dalton)

On May 23 the engineer arrived in Hamilton to carry out the programme of precise levelling required by the city: the levelling at Hamilton being completed on June 7, the engineer then proceeded to Cobalt, Ont., and was joined by his regular field party.

Precise levelling was commenced at Latchford, about 9 miles south of Cobalt, where work had been left off in November, 1921, and carried north along the Timiskaming and Northern Ontario railway to a point 6 miles north of Porquis Junction. Connection was made here with the levels from the north thus closing the large circuit—North Bay—Sudbury—Port Arthur—Winnipeg—Cochrane.

The following branch lines, from the main line of the Timiskaming and Northern Ontario railway, were also run: Earlton Junction to Elk Lake, 28 miles; Porquis Junction to Timmins, 33 miles; Porquis Junction to Iroquois Falls, 7 miles.

A number of permanent bench-marks were established in the towns of Cobalt, Haileybury, New Liskeard, Porquis Junction, South Porcupine, Schumacher, Timmins and Iroquois Falls.

The season's work was completed on September 28, when the party was disbanded.

Detail of work accomplished: Double levelling, 225 miles; bench-mark piers built, 11; permanent bench-marks established (including piers), 109; Hamilton city bench-marks connected, 37; Public Works bench-marks connected, 17.

Precise Levelling in Northern Ontario and the City of Quebec

(G. E. B. Sinclair)

The work outlined for this party was the continuation eastward of the line of precise levels along the Canadian National railway (old National Transcontinental railway) through northern Ontario. This line of levels had been commenced in 1920 near Rennie, Man., at the junction of the Canadian Pacific railway and Canadian National railway. At the end of the 1921 field season the work had been carried to Kabina, 21 miles west of Hearst, Ont.

The camps in 1922 were Hearst, Lowther, Kapuskasing, Jacksonboro, Cochrane, Hughes and Lowbush River. While camped at Cochrane instructions were received to run precise levels and establish bench-marks south from Cochrane over the Timiskaming and Northern Ontario railway for a distance of 21 miles. The party disbanded on August 14 at Lowbush river, on the Canadian National railway, 41 miles east of Cochrane.

During the season eighty-eight bench-marks were established. They are classified as follows: Standard bench-mark piers, 16; bridges and culverts, 58; buildings, 11; masses of rock, 2; mass of concrete, 1.

Rain caused an average loss of three days a month during the season. Otherwise weather conditions were good.

One interesting feature of the season's work was that this year the accumulated discrepancy between forward and backward levelling was plus 0·137 foot, while each previous year it has been minus in sign.

During the season field elevations for bench-marks were furnished to several power companies, railway officials and the town engineer of Cochrane.

After the close of the regular precise levelling programme, as above noted, work was begun at Quebec on October 23 and completed on November 3. The work outlined was to run precise levels throughout the city of Quebec, establishing bench-marks at such points as the city engineer desired.

With the need for economy in mind, it was decided to run single levelled cross city lines and loops wherever feasible. This was possible as a loop around the city had been run in 1919 with a closure of 0·020 foot.

The amount of single levelling was 13·36 miles and the duplicate levelling 5·37 miles—equivalent to 12·05 miles of duplicate levelling in all. The steep grades, narrow streets and heavy traffic made progress slow. On the steep grades it was necessary to take sights as short as 12 to 15 feet.

The churches, hospitals and other public buildings afforded good locations for bench-marks. There were also three bench-marks established in geodetic triangulation monuments on the outskirts of the city. A total of twenty-seven bench-marks was established. The bench-mark tablet used is the same as that used on the English river and Winnipeg river work. It has a three-inch

shank and three-inch disk face inscribed with the words "Geodetic Survey of Canada, Ottawa, B.M.". A chisel is held on the elevation the same as with standard copper bolt bench-marks.

Precise Levelling in Saskatchewan and Alberta

(G. S. Raley)

Work was started on May 2 from Topographical Surveys' bench-mark S-76 in Alsask, which was already connected with the Geodetic Survey precise level net. The line was later closed on Topographical Surveys' bench-mark Z-45, on the Canadian Pacific railway, in the vicinity of Compeer, Alta.

This line was across country, over rolling prairie with hills from 35 to 75 feet high. Progress was necessarily slow on account of the short length of sights—as many as twenty-two to twenty-seven set-ups in a mile. Transport difficulties due to the muddy condition of the roads were also experienced, especially in the early part of the season. An extra man was used on this work with an Abney hand level. He preceded the line party, picking out instrument stations and positions for the forward rod. Steel pins about 14 inches long with rounded tops were used for turning points, being driven at least 12 inches into the ground.

After this line was completed camp was moved to Kerrobert, Sask., and, starting from Topographical Surveys' bench-mark Z-56 the line ran northwest to Macklin and thence northeast to Unity, connecting with bench-mark 22-H in Unity station. Two bench-mark piers were placed adjacent to the crossing of the 10th base line near Salvador, Sask., and connection was made with Topographical Surveys' bench-mark No. 4 on the 11th base line near Senlac.

From Unity camp moved to Camrose, Alta., and starting from bench-mark 70-F a line was run westward to Wetaskiwin, connecting with Topographical Surveys' bench-marks H-42 and H-44.

During the summer 40 miles cross-country and about 136 miles of double levelling along the railways were completed. Bench-marks were established as follows: Standard concrete piers, 37; buildings, 15; bridges, 1; other bench-marks connected—Irrigation Survey, 4; Topographical Surveys, 8.

The party was disbanded for the season at Wetaskiwin, Alta., on October 13.

Precise Levelling in British Columbia

(N. H. Smith)

Work was started at Revelstoke, B. C. May 8. Elevations were established along the branch line of the Canadian Pacific railway, between Revelstoke and head of the Arrow lakes. On May 22 camp was moved to Sicamous and work was continued along the branch line of the Canadian Pacific railway between Sicamous and Okanagan Landing. At the request of the Public Works Department bench-marks were established at the heads of the Arrow and Okanagan lakes.

Camp was moved to Spence Bridge on June 16, a distance of 157 miles, whence levels were run along branch line of the Kettle Valley railway to Brodie, where a bench-mark was established on the main-line of the Kettle Valley railway (the intention being to tie in with this bench-mark when line of levels is run along main line of the Kettle Valley railway from Hope.)

From Brodie, camp was moved to Mission on July 17, a distance of about 100 miles, whence levelling was continued easterly along the main line of the

Canadian Pacific railway to Hope, where work for this season was terminated on August 11.

Levelling from a bench-mark previously established at Mission to a bench-mark previously established at Hope, the error of closure by the new route was 0·002 foot—the perimeter of the circuit being 98 miles.

During the course of the season, elevations were given out (as computed in the field) to the following engineers; City Engineer of Vernon, District Engineer of the Public Works Department at Nelson and District Engineer of the Water Rights Branch at Kelowna.

Winter Precise Levelling Along the Winnipeg and English Rivers

(R. H. Montgomery)

The Extent of Levelling Operations.—From Pelican falls, on the English river, following the natural water course down to the Winnipeg river and from Kenora down the Winnipeg river to Fort Alexander on lake Winnipeg, the distance by canoe is roughly 450 miles. While it would have been possible to carry out precise levelling along such a water course during the summer months by following the shore line, it was recognized that the actual mileage of levelling would be increased to three or four times the distance as travelled by canoe, and proportionally would the cost be increased. The alternative was to carry out the operations during the winter when the distance would be the same as ascertained by canoe—or even might be shortened. In the past precise levelling has been successfully attempted on ice, over lakes and rivers, but only to a limited extent. However, to attempt to carry out in one winter precise levelling operations involving 450 miles, along a water-course where known obstacles such as open water at every falls, cascades and rapids might be expected, through a district that presented unusual transportation problems due to the sparse settlement and heavy snowfall, would entail careful consideration and would require unusual preliminary investigation in order to ensure a successful conclusion. Mr. R. H. Montgomery was accordingly requested to make this investigation for Geodetic Survey and to report on the feasibility of completing the work in one season.

Preliminary Investigation.—In company with Mr. E. Patterson, A.M.E.I.C., of the Winnipeg staff, Dominion Water Power Branch, the engineer, starting from Sioux Lookout, made a trip by canoe over the entire course in July. Subsequently a report was submitted outlining the difficulties involved and suggesting what appeared to be the proper manner of carrying out these operations with regard to organization, transport and arrangements required prior to the actual work, an estimate of the cost, and finally a favourable report on the feasibility of completing the operations in one season.

Preliminary Organization.—The character of the country and the season of the year determined the nature of the transport, namely, dogs and toboggans. In view of the limitation of dog transport it was necessary to reduce the weight of camp equipment provisions and dunnage to a minimum. Points along the course were selected for supply bases so that a field party during the work would never be more than 20 miles from one of them. During the fall, provisions and dog feed were placed in these bases. During the same period, some thirty dogs were purchased in the Icelandic settlement near Gimli, Man., and also the unusual transport equipment, such as toboggans and dog harness, was arranged for.

Duration of Field Season.—One of the results of the preliminary investigation was the determination of the period that could be counted on as suitable for winter levelling. These water courses are peculiar in many respects—outstanding of which is the lack of a continuous ice covering. The North Saskatchewan river, running through a zone having about the same temperature

range and with an average current of 4 miles an hour, will freeze over about the middle of November and have a continuous ice covering until the middle of April. The English and Winnipeg rivers are more properly described as a chain of lake-like expansions connected by narrows; in these narrows are found cascades and falls; except just above and below each cascade there is very little noticeable current. It would be natural to expect that such a water course would tend to maintain an excellent ice cover, but it was found that wherever there was any indication of a current there was no permanent ice cover. In such places after a spell of 40° below zero weather, ice cover might form to a depth of 6 inches, but with rising temperature this ice would wear away from underneath until only a shell remained. This was a continual menace for, if during the ice-forming stage it was covered by a blanket of snow, a trail which was safe one day might be unsafe the next with no visible signs of weakness to give warning. Under ordinary conditions dog transport started on this water course around December 1 and lasted until the end of March. However, the levelling period was limited to December, January and February, as it is possible to carry on operations with the temperature below freezing, even if there is no continuous ice cover, whereas it is impossible to level over a continuous ice cover with the temperature above freezing on account of the instability of the turning points.

Field Operations.—The field work was divided into three sections—western, central and eastern. The western party under Mr. W. J. Lowndes started levelling on December 6 at Fort Alexander and worked up the Winnipeg river reaching its confluence with the English river on February 20. An average of 49 miles per month was maintained on this section. This party then moved to Favel and between February 26 and March 3 a connection of 14 miles was levelled from Favel to Grassy Narrows.

The central party, under Mr. G. S. Raley, started at Kenora, worked down the Winnipeg river and up the English river, meeting the eastern party near Grassy Narrows on March 4. In the first half of the season this party was retarded by bad ice conditions. The average maintained was 34 miles per month.

The eastern party, in charge of Mr. G. E. B. Sinclair, started levelling on December 4 at Hudson and worked down the English river. Between December 24 and January 5 a water transfer of levels under ice cover was carried on lac Seul. This party met the central party near Grassy Narrows on March 4. All parties were disbanded at Favel by March 6.

Weather Conditions and their Effect on Levelling.—In general with all winter work the weather proved to be the controlling element and it is doubtful whether a more unfortunate year could have been selected for this work. November was unusually mild so that on December 1 there was not more than two or three inches of ice, even on the lakes. Cold weather set in early in December, but not before a heavy fall of snow had covered the thin ice and prevented thicker ice from being formed. An excessive amount of snow fell in December and it was not until the weight of this snow cracked the ice beneath and allowed the water to flood up to the top of the snow that a safe ice cover was formed. All through December this process was going on and levelling operations were retarded, as the percentage of relevelling was high and slush made walking difficult. In January the weather was less severe and with less snow the ice conditions were better. February was noted for high winds and storms. Wind proved to be the most disturbing element as it was found almost impossible to level in a stiff breeze even on twenty-four inches of ice. In effect, it was as if waves were undulating through the ice sheet very much as if the ice consisted of a plastic substance like asphalt. With a stiff breeze, the ice surface did not change in absolute elevation to any noticeable degree, but it was impossible to keep the bubble in the level vial stationary for even the small period of time required between forward and backward readings.

Precise Levelling during the winter on rivers of Northwestern Ontario.

Precise Levelling during the winter along rivers in Northwestern Ontario.

Every method was attempted to overcome this obstacle with but little success, and in the end on windy days no levelling was attempted unless the observer could arrange his work to keep the instrument always on solid ground. Since this was not always possible, considerable time was lost in February on account of wind. On the 1st of March a thaw set in, the snow on the ice rapidly turned into water and the ice became honeycombed. This caused so much settlement of turning plates and instrument as to render levelling impossible. It now became apparent that any possibility of carrying on levelling operations on ice with the temperature above freezing could not be counted on. Fortunately, on March 3, the weather turned colder and the small amount of levelling remaining was finished.

Water Transfer.—One result of the preliminary investigation was the reduction of the actual mileage to be covered by levelling. By tying in the bench-mark at Pelican falls with a spur line and starting the main line of levels at Hudson and following the winter trail to lac Seul Post a saving of 20 miles was effected. Lac Seul itself presented a good opportunity to carry a water transfer under ice cover and, as this method has proven efficient and precise if carefully carried out it was decided to attempt it. Between lac Seul post and Pine Ridge post, a distance by water travel of 60 miles, there is only one narrows, Shanty narrows, where there is any appreciable drop. By taking simultaneous readings spread over several days on four gauges, one at each end of the lake and one at each end of Shanty narrows, it was felt that a very accurate determination should be possible. Water transfer during summer months has been attempted with varying success, since the attainment of accurate results requires ideal conditions, for a short period, or, with ordinary conditions, the mean of observations spread over a long period, and for these reasons it has generally been discarded. Water transfer under cover of ice has been little used in the past and therefore few records are available as to its efficiency. Judging from the results obtained on the lac Seul transfer, it is efficient, precise and economical; hence, whenever the opportunity offers, it should be made use of. It is economical because it would appear that approximately the same accuracy obtained by water transfer in summer could be secured in one-tenth the time if taken under cover of ice. Largely due to the two instances cited, the actual amount of levelling was reduced from 450 miles to 364 miles and a saving of some $2,000 ensued, and still the information required was not affected in any respect.

Bench-Marks.—The bench-marks were the standard Geodetic Survey tablet cemented by lead into bed rock. The route lying in Laurentian formation with frequent outcropping of rounded granite permitted the planting of bench-marks of a most permanent character. As the locations of these bench-marks were important to the Dominion Water Power Branch, it was decided to leave the actual planting to its staff. Mr. Patterson of that branch spent September and October on the planting of sixty-five permanent bench-marks. In general every possible power development along the route has a bench-mark in close proximity. At the time of placing these bench-marks any bench-marks of the Water Power Branch surveys or of other organizations were tied in to them. Consequently it is now possible to reduce all former surveys to sea-level datum. The average distance between permanent bench-marks was about 5 miles.

Precision Attained.—In all geodetic operations where extreme accuracy is the goal, it has been recognized that the time factor is decidedly a variable quantity. In precise levelling the time required to level a certain line varies according to weather conditions; under certain conditions it might easily take twice as much time as under other conditions. While previous experience tended to show that with proper organization (for instance no lost time of the levelling party such as might occur on moving day) an average of 40 miles a

Dog team used for Precise Levelling during the winter on rivers in Northwestern Ontario.

month could be expected on this work, still an unfavourable season would upset all precedent. In these operations, where a definite mileage to be levelled in a certain fixed time created a condition that was foreign to good levelling practice, the results are more than usually interesting. At the start each unit was given certain objectives and the usual precise levelling procedure carried out in summer was followed with minor modifications to conform with the changed conditions incidental to winter work. As the work progressed these objectives were changed slightly to compensate the varying rate of the different units, and in this manner the total work was carried out in the scheduled time. The usual limit of ±0.017 foot between the backward and forward lines over each mile section was rigidly adhered to, except in a few isolated sections on the eastern division. However, the precision of field operations is more properly judged by closures of circuits than by the individual discrepancies and, fortunately, by the proximity of previous precise level lines in the vicinity of this work closures were obtained for the entire line, except the most westerly 35 miles. Connections were made to previously run Geodetic Survey lines at Hudson, Favel, Minaki and Kenora. By making use of a secondary line of levels from lac du Bonnet to Molson, run by the Topographical Surveys Branch, corroborative, if not conclusive, evidence was obtained of the line from the confluence to lac du Bonnet.

The following table indicates the field closures:—

Circuit	Perimeter	New Levelling	Closure Field	Calculated *Average
	Miles	Miles		
Hudson to Favel	260	172†	+0·09	±0·21
Favel to Minaki	147	111	−0·04	±0·12
Kenora to Minaki	125	19	−0·17	±0·10
‡Minaki to Molson	220	119	+0·03	±0·18

*The average closure of 42 circuits of the Geodetic Survey of Canada precise level net is 0·0008 M foot where M is the perimeter in miles.

†Includes 60 miles in lac Seul water transfer.

‡This circuit includes Topographical Surveys' secondary line from lac du Bonnet to Molson.

Examination of this table speaks rather conclusively of the precision attained on this work, comparing favourably with precise levelling over railways in summer months.

Conclusion.—The completion of these operations in one season and the precision attained, as evidenced by the closures, are viewed with satisfaction. When this work was first contemplated there was considerable diffidence as to the final outcome, as there is no parallel example of precise levelling on such an extensive scale having been carried out during the winter months. The successful conclusion, therefore, is all the more gratifying, especially as the past season could not be considered as exceptionally favourable for work of this nature, but rather the reverse.

Reconnaissance for Secondary Triangulation North of Yellowhead Pass, British Columbia–Alberta Boundary

(H. F. Lambart)

At a conference held in Edmonton in the autumn of 1921 between the Boundary Commissioners of Alberta and British Columbia and a Dominion representative, it was arranged that the Geodetic Survey be asked to assist in the Interprovincial Boundary Survey, by establishing secondary triangulation control north of the Yellowhead pass.

A three years' programme was laid down, which, when completed, will consist of a net of secondary triangulation between a base line and Laplace point at Yellowhead pass, and a base and Laplace point at Jarvis pass, which is near the intersection of the 120th meridian with the continental divide.

The programme for the first year consisted of a reconnaissance by one party for the selection of stations. The experience and progress of this first year was to give information on which the second and third year's programmes could be based. The reconnaissance party, comprising four men, engineer, assistant and two packers, was organized at Jasper, Alta., and left there on June 15, a pack train of fourteen horses affording the means of transportation. The snow in the mountains does not permit of work at an earlier date.

After completing the location of the base on the Yellowhead lake, the party's progress northward with the reconnaissance followed the valley of the Miette river, crossing "Pass No. 1," then the head waters of Grant brook and through Shale pass on to the head waters of the south branch of the Stony river.

The triangulation net here crossed over to the west side of the Continental watershed, the trail going over the pass from there into Colonel creek. The Colonel is then followed to its junction with the Stony river, east branch of the Moose river. The east branch of the Moose river is then followed to its head and the Continental divide crossed in going over the Moose pass into Calumet creek. The trail follows down the Calumet and down the Smoky river. The valley of the Smoky is left at Bess pass. At this pass the divide is again crossed and within a few miles again crossed back to the eastern side of the watershed by going through the Jack Pine pass. This pass leads directly to the head waters of the Jack Pine river. The Jack Pine is followed to the middle fork where the trail ascends 2,000 feet and crosses the divide on Big Shale mountain into the waters of the Little Smoky river.

The work for the season terminated in this neighbourhood and on August 28 the party commenced to retrace its steps.

The old trail was followed as far back as its junction with the Calumet. From here a shorter route to the railway was taken by way of Robson pass to the Valley of the Thousand Falls.

Between the 11th and 20th of July a gap was made in the regular proceeding of the reconnaissance work to return to Jasper to co-operate with the Air Board in a series of flights taken from Henry House to the Jarvis pass. Of the four attempts made to cover the whole distance, one with Mr. A. O. Wheeler and the other three with H. F. Lambart as observer and photographer, only the one on July 16 proved entirely successful, owing to the unfavourable weather conditions. This one flight well repaid all the trouble and time taken, as it enabled a complete examination of the country to be made and detailed information available of that very little known locality of the Sir Alexander and Mount Ida group of glaciated peaks, and to obtain a very valuable collection of photographs.

A summary of the work is as follows: Extent of reconnaissance in miles, 75; number of square miles within the net, 240; number of triangulation stations established, 28; boundary monuments to be connected with the scheme, 2; total number of intersection stations including peaks and topographic cairns, 36.

Primary Triangulation in British Columbia

(G. H. McCallum)

On the Pacific coast the triangulation programme for the season consisted in the continuation of the main scheme of triangulation towards the north, and in the connection of the Oyster Bay base line with the primary scheme in that vicinity. All of this work is on part of an arc of primary triangulation which will eventually be extended from Puget sound up the coast and through Yukon and which is being carried on in co-operation with the United States Coast and Geodetic Survey.

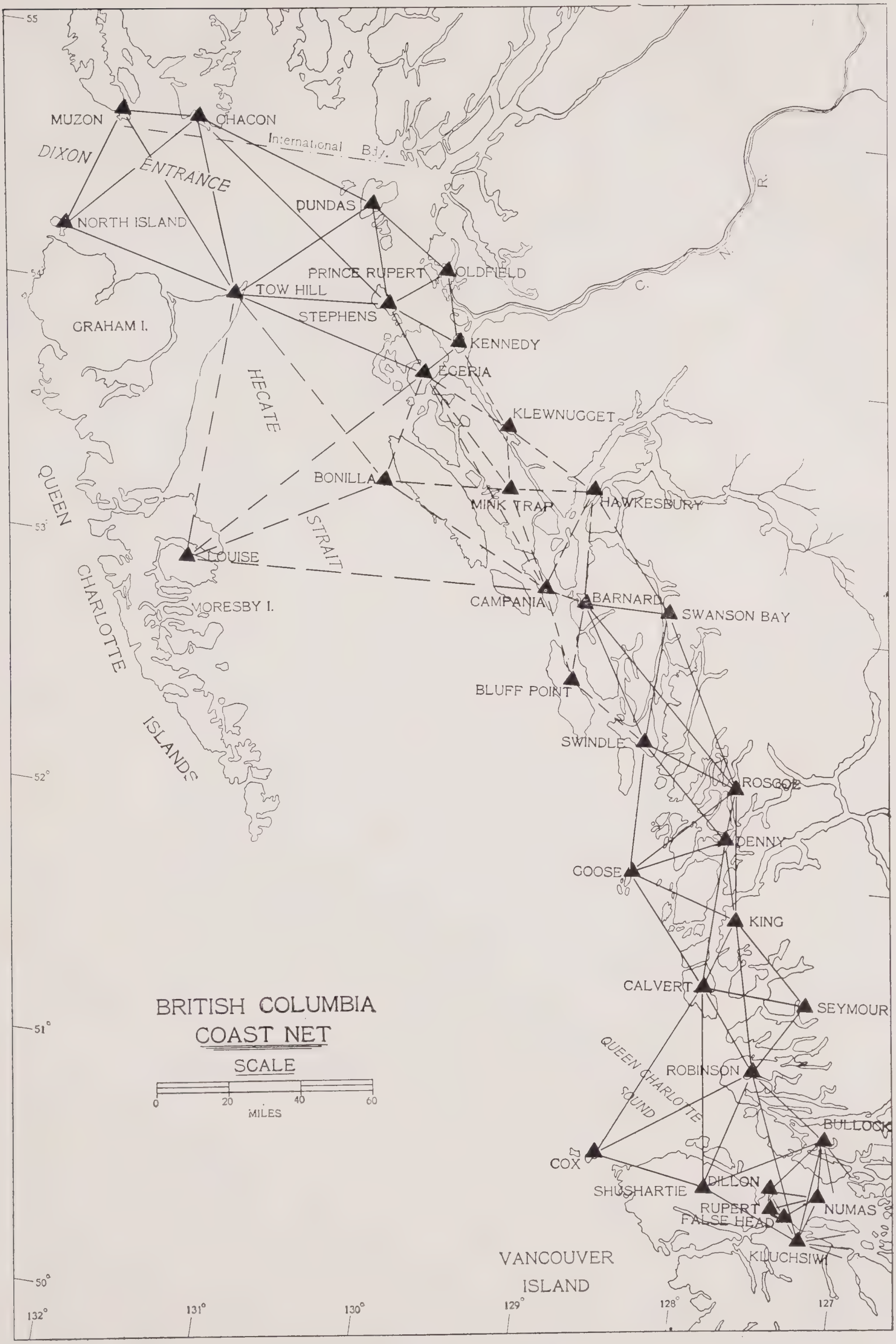
The party left Vancouver on May 12 for the base camp at Fort Rupert, near the north end of Vancouver island, where the outfit had been stored from the previous season. Here the equipment was sorted out and overhauled, and from here the parties were placed on the various stations, the observing parties occupying Goose and Denny stations first.

As usual the party was split up into two observing parties of four men each; five lightkeeping parties of two men each and a station preparation party of four men. These, with the cook and engineer of the launch "Metra", made twenty-four men all told.

As is well known, the weather is the uncertain factor in the progress of the survey, especially in the region north of Vancouver island, and in this respect the party was especially fortunate. The season on the coast was remarkably dry and, as a consequence, in the settled parts around Vancouver and as far north as the north end of Vancouver island, forest fires were prevalent from the middle of June until the middle of August, making reconnaissance or observing impracticable. Further north, in the vicinity of Swanson Bay where the party was working, the same fine weather was encountered, but with no fires, making ideal weather for observing, except for occasional fogs on the off-shore stations.

The party moved south to the Oyster Bay base line and arrived there on August 11, the day after the first rain came. This was followed by more wet weather and although the fires were not extinguished for some weeks, the atmosphere was cleared sufficiently for observing.

The new electric signal lamps gave good results when properly pointed and focussed. The small arc covered by the beam of light makes accurate pointing essential, particularly on long lines, which is made difficult by the errors of the compass and of the plotting of the positions of the stations on the charts. To overcome this difficulty, the practice was followed of having the engineer call


BRITISH COLUMBIA
COAST NET
SCALE
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20
40
60
MILES
MUZON
CHACON
DIXON
ENTRANCE
International Bdy.
NORTH ISLAND
DUNDAS
PRINCE RUPERT
OLDFIELD
TOW HILL
STEPHENS
GRAHAM I.
KENNEDY
EGERIA
HECATE
KLEWNUGGET
BONILLA
MINK TRAP
HAWKESBURY
QUEEN
CHARLOTTE
ISLANDS
STRAIT
LOUISE
MORESBY I.
CAMPANIA
BARNARD
SWANSON BAY
BLUFF POINT
SWINDLE
ROSCOE
DENNY
GOOSE
KING
CALVERT
SEYMOUR
QUEEN CHARLOTTE SOUND
ROBINSON
BULLOCK
COX
DILLON
SHUSHARTIE
RUPERT
NUMAS
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C.
55
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the lightkeeper by light and give him line, whenever the latter started showing light from a new station.

The current used with the lamps was from Edison alkaline cells, type B-4. These are sold in batteries of five cells each, giving a current of six to eight volts. This battery weighs nearly fifty pounds and makes a decidedly awkward pack as the cells cannot be sealed for long and the electrolyte unsealed is liable to get spilled. So the batteries were cut down to three cells and new frames made for them, and rubber corks used to stop the vents when packing them to the stations. These were loosened every fifteen minutes to allow the gas to escape. This new battery weighs from twenty-five to thirty pounds and is much more convenient to pack. It supplies a current of 3·6 volts which gives satisfactory results with the small 3·7 volt bulb commonly used. If the larger 6 to 8 volt bulb is required, two batteries in series supply current at 7·2 volts, which is ample.

During the season co-operation was maintained with the survey parties of the British Columbia Government, and a number of triangulation stations were located along the shore as controls for their survey of timber limits and pre-emptions. The positions of a number of points were also established for the Hydrographic Survey. In all, twelve primary stations were occupied and completed, six supplementary stations established and the positions of five lighthouses determined. The party returned to Vancouver on October 1.

With average weather conditions it is hoped that 1923 will complete the connection of this part of the triangulation with the southeastern Alaska system of primary triangulation of the United States Coast and Geodetic Survey. When the latter system has been extended by the Geodetic Survey of Canada through Yukon a connection will be completed with the Alaska-Yukon Boundary Survey's secondary triangulation along the 141st meridian from the Arctic ocean south almost to mount St. Elias.

The completion of this work will give an arc of primary triangulation from California to the Arctic ocean, a distance of some 2,500 miles.

Primary Triangulation Along the 49th Parallel

(W. M. Dennis)

During 1921 two reconnaissance parties had located 500 miles of triangulation along the 49th parallel, eastward from the 109th meridian. The work carried out during the season of 1922 has been in accordance with the desire to push forward simultaneously the different operations necessary to complete this scheme of control along the International Boundary.

Four parties were organized and placed under the charge of Messrs. Monteith, Dunn, Douglas and MacTavish, to carry out respectively, direction measurement, permanent marking of stations, tower building and reconnaissance.

Direction Measurement.—The direction measurement party consisted of an engineer, recorder, cook and one senior lightkeeper, with the usual equipment for camping. Their transport consisted of two trucks; one was used for moving the camp outfit and the other for attendance on signal lamps.

The atmospheric conditions for the past season were unusual in this district. Although fine weather seemed to prevail as usual, there was a loss of time on this party of 21 per cent. This was apparently caused by smoke from forest fires in British Columbia, which became so diffused in travelling this distance that it was not noticeable except when looking for points at a distance. This condition was so widely distributed that local showers, when they did occur, improved the visibility only for a very short time.

For some time the United States Coast and Geodetic Survey has been looking into the possibility of using automatic time switches to control the

Twenty-foot Tower on Triangulation Station along the 49th Parallel, contains 1,000 feet of lumber and can be erected in two days.

electric signal lamps and thus reduce materially the number of lightkeepers. Under the necessity of reducing as much as possible the appropriation for the 49th parallel, and at the same time carrying on all the operations necessary to obtain results in the most economical manner, it was decided to equip the party with one of the types of time switches now on the market and used for electric sign controls. This worked quite satisfactorily and resulted in a saving of approximately twenty dollars per day in the operation of the direction measurement party.

The electric signal lamps in use by this survey were connected, through this time switch, to the dry cells supplying the energy. Each switch is controlled by a clock capable of keeping fairly accurate time for one week. This switch is thrown " on " and " off " in each 24 hours, by mechanism controlled by two indicating dials which may be set to have each throw of the switch take place at any required hour. By means of this equipment one lightkeeper with a reasonably fast truck, can, in a country in which direct routes may be found, maintain the lights necessary for one observing party. It may be found necessary to supply this lightkeeper with an assistant.

This party organized on May 10 at Shaunavon, the nearest railway point, was encamped May 18 at the commencement of their work, 50 miles south of Shaunavon. Unusual weather conditions caused this delay. Here, in co-operation with the party on station preparation, they built one 20-foot tower, placed four piers, and on June 5 were ready to begin the measurement of directions. This work was closed down on September 9, and the results summarized on page 31 were obtained in this period of ninety-seven days.

Station Preparation.—A station preparation party consisting of three men with a motor truck placed the piers to mark permanently the triangulation stations. These piers were in two sections—the base, 1½ feet square and 2 feet deep, set 4 feet below the surface of the ground, carried the sub-surface mark in its upper face. On top of this, but separated from it by tar paper, the pier carrying the surface mark was built. The tar paper is cheap, convenient to work with and prevents all adhesion, so that a subsequent disturbance of the surface mark will not disturb the base. It was at first intended to place 2 inches of sand between the upper pier and the base, but after building 2 piers this was found unsatisfactory and the paper was substituted. The upper pier, 1½ feet square at the bottom and 1 foot square at the top, is 5½ feet long and carries the surface mark in its upper face. This pier extends 1½ feet above the surface of the ground and acts as a monument. The surface and sub-surface marks are the standard triangulation station tablets and are placed in the same vertical line. By agreement between this Survey and the United States Coast and Geodetic Survey, the marks of the Geodetic Survey of Canada were used on stations in Canadian territory and those of the United States Coast and Geodetic Survey used on stations in United States territory.

It was difficult to conduct this work with the desired efficiency as it was essential that each base should set twenty-four hours before the top pier was built. Where possible, stations were prepared in pairs, with the camp approximately midway between them, and by working alternately on the two stations considerable delay could be avoided. The difficulty of locating suitable sand and gravel for concrete, and the long hauls necessary when material had been located, kept the truck in almost constant use.

Tower Building.—The tower building party, consisting of a foreman, assistant, five labourers (later reduced to three) and a cook, rapidly developed efficiency.

The transport of this party consisted of one truck and a team of horses, with double-decked wagon. The work moved along slowly at first on account of bad roads, slow transport and long distance between successive camps.

A month later, however, this party reached the flat country east of the 103rd meridian, where the towers are close together and close to the railway. For the remainder of the season transport caused no unusual delay and the work proceeded very fast.

Reconnaissance.—In 1921 the reconnaissance engineer, locating the eastern section of the triangulation along the 49th parallel found it inconvenient to maintain an average width of the scheme greater than 7·5 miles between the 99th and 102nd meridian. It was also found convenient on account of the topography to make a detour to the north of the Turtle mountains. This placed some sixty miles of the triangulation chain entirely in Canadian territory, with no points available for control on the United States side of the boundary. On account of the international character of this particular triangulation, it was decided to look into the possibility of an alternative scheme over these mountains, to give to the adjacent United States territory the amount of control that might be expected under the terms of the agreement concerning this work. This matter was investigated in June, 1922, and it was decided that such a scheme was feasible. Work was begun immediately from the line Dunbar-Lignite, and continued eastward 120 miles to the point Ninga H, as shown on the sketch of this work, page 40 of the Geodetic Survey report for 1922. The connection with the original scheme to the east of Ninga H it is expected will be made satisfactorily with two more quadrilaterals.

This alternative scheme has an average width of 9·6 miles, as compared with 7·5 miles in the original, and twenty-nine stations have been replaced by twenty-two new points. The number of towers remains the same, but the average height has been increased from 30·5 to 43·2 feet.

SUMMARY

Reconnaissance—	
Number of points visited	78
Number of stations selected	23
Number of days selecting stations	60
Number of days of field duty	106
Area in square miles	1,150
Tower Building—	
Number of towers built	18
Average height	37·9 ft.
Number of days on tower building	71
Number of days on field duty	120
Station Preparation—	
Number of piers built	20
Number of days building piers	63
Number of days of field duty	120
Angle Measurement—	
Primary—	
Number of stations completed	15·5
Number of stations reoccupied	5
Average length of lines in miles	15
Area in square miles	1,515
Supplementary—	
Number of stations completed	3
Number of International Boundary stations tied in	7
Number of Land Survey marks tied in	15
Number of precise level bench-marks tied in	1
Number of days occupied in angle measurement	60
Number of days of field duty	121

Secondary Triangulation for Port Arthur and Fort William Harbour and the City of Quebec

(A. M. Grant)

The first work undertaken was the establishment of a secondary triangulation control for the surveys and engineering works in the vicinity of Port Arthur and Fort William, and the preliminary reconnaissance for a primary base net in the same district.

The engineer left Ottawa on April 27 and established nine secondary triangulation stations around Port Arthur and Fort William as shown on the sketch on page 33, the azimuth as well as the latitude and longitude being obtained from the primary triangulation station on mount McKay. The lengths of lines were obtained by measuring a secondary base line about a mile long on the concrete breakwater in front of Port Arthur.

The distance control for the primary triangulation in this locality had been obtained from the long lines of the United States Lake Survey across lake Superior, and as some distortion was shown in our triangulation as a result of holding as fixed several of these lines, it was considered advisable to have a primary base net laid out, ready for any extension of the primary triangulation which might be necessary in the future. Accordingly a base net was laid out involving the establishment of six new primary stations. This base net can be used and the base line measured when any demand comes for further primary work in this district. The work was completed on May 23.

On September 25 the engineer left for Quebec to lay out a scheme of secondary triangulation for the control of surveys in the city of Quebec and the surrounding district. The result of the work is shown on the sketch on page 34. The latitude, longitude, azimuth and distance were all obtained from the primary triangulation in that district, the work being based on the line Belair-Quebec.

In this work the city of Quebec bore the expense of the labour and materials used for establishing all the stations in and close to the city, the laying out of the work and the direction measurement being done by the engineer. The directions were all measured with a 12-inch theodolite.

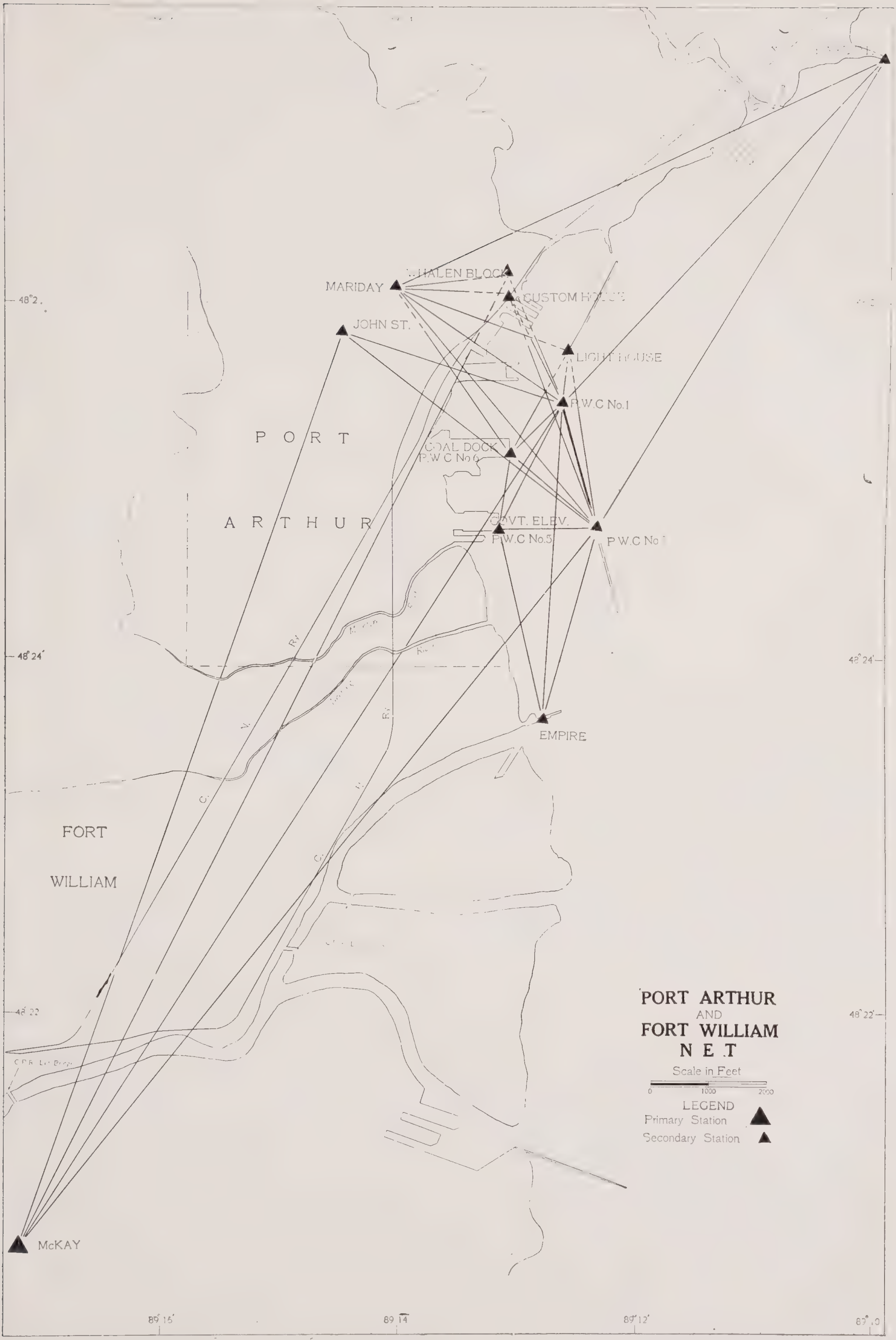
This work was completed on November 18 except the setting of the reference bolts in the streets and connecting them to the triangulation points, which is expected to take two or three weeks of the season of 1923.

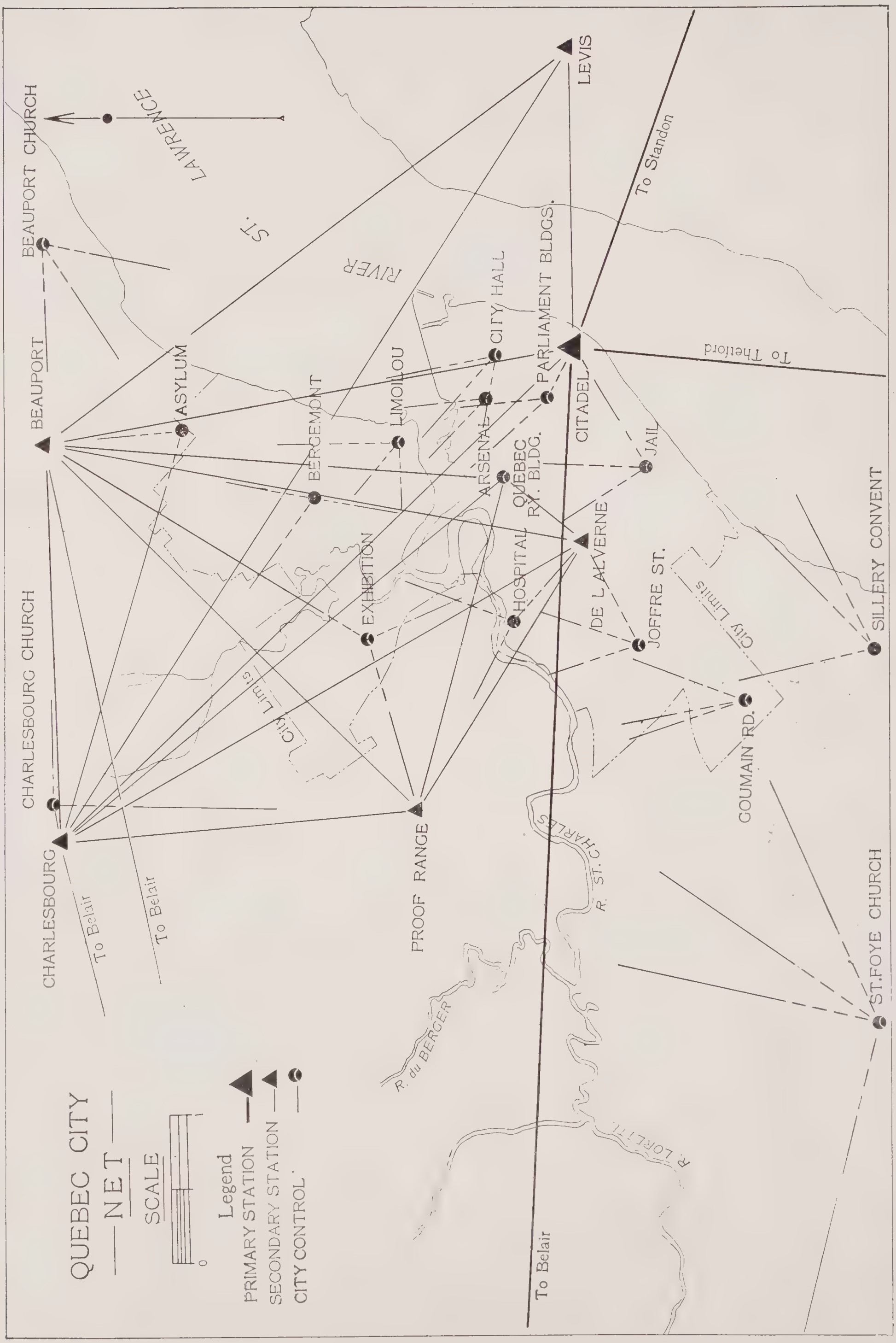
At Port Arthur some very abnormal conditions of refraction, both vertical and horizontal, were noticed in the lines passing close to the cold water of lake Superior, especially at the close of a day when the sun had been fairly strong. There was enough variation in vertical refraction to produce a vertical distortion of 6 feet in a signal. It was particularly noticeable that on nights when the vertical distortion was at its maximum there was also a large horizontal displacement of the image. The former was large enough to be plainly evident to the observer without making any angular measurement, while the latter showed in the results. The conclusion was that when abnormal vertical refraction is evident the observer should be very watchful for indications of horizontal refraction also.

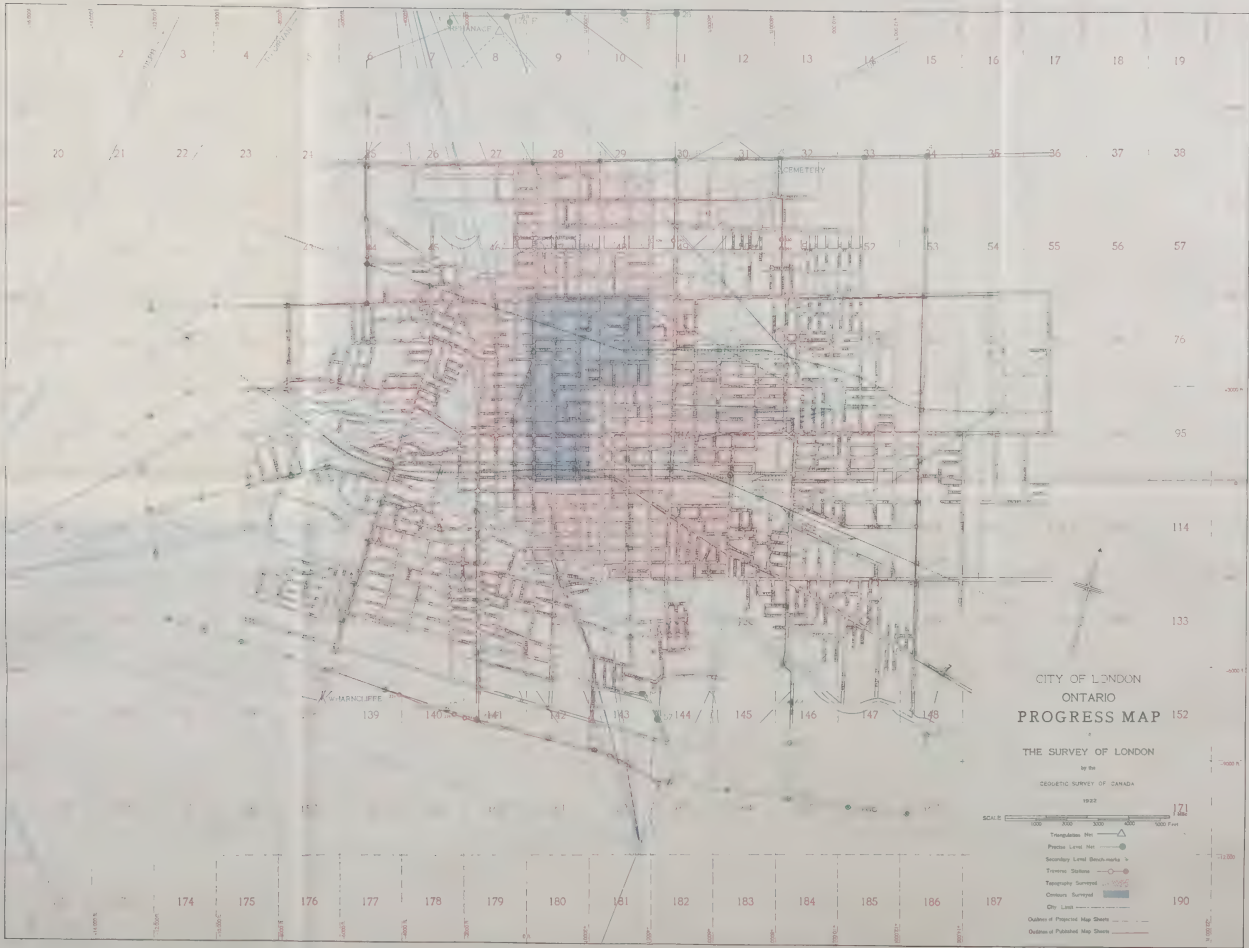
City Mapping

(Douglas H. Nelles, Supervisor of Topography)

The work of city mapping by the Geodetic Survey of Canada has been confined to the city of London, Ont. The undertaking is of an experimental nature, to find the best combination of old and new methods. The staff on the work has been kept small and the operations spread over a number of years. Each year has shown a decrease in the unit cost due to improvements in


PORT ARTHUR
AND
FORT WILLIAM
N E T
Scale in Feet
0
1000
2000
LEGEND
Primary Station
Secondary Station
MARIDAY
JOHN ST.
CUSTOM HOUSE
P.W.C No.1
COAL DOCK
P.W.C No.6
GOVT. ELEV.
P.W.C No.5
EMPIRE
McKAY
PORT
ARTHUR
FORT
WILLIAM
48°24′
48°22′
89°15′
89°14′
89°12′


QUEBEC CITY
NET
SCALE
0
Legend
PRIMARY STATION
SECONDARY STATION
CITY CONTROL
ST. LAWRENCE
RIVER
LEVIS
BEAUPORT CHURCH
BEAUPORT
ASYLUM
BERGEMONT
LIMOILOU
CITY HALL
ARSENAL
PARLIAMENT BLDGS.
CITADEL
QUEBEC RY. BLDG.
JAIL
DE L'ALVERNE
HOSPITAL
EXHIBITION
JOFFRE ST.
SILLERY CONVENT
GOUMAIN RD.
CHARLESBOURG CHURCH
CHARLESBOURG
PROOF RANGE
ST. FOYE CHURCH
To Standon
To Thetford
To Belair
To Belair
To Belair
City Limits
City Limits
R. ST. CHARLES
R. du BERGER
R. LORETTE



CITY OF LONDON
ONTARIO
PROGRESS MAP
THE SURVEY OF LONDON
by the
GEODETIC SURVEY OF CANADA
1922
SCALE
1000 2000 3000 4000 5000 Feet
1 Mile
Triangulation Net
Precise Level Net
Secondary Level Bench-marks
Traverse Stations
Topography Surveyed
Contours Surveyed
City Limit
Outlines of Projected Map Sheets
Outlines of Published Map Sheets
CEMETERY
WHARNCLIFFE
2 3 4 6 7 8 9 10 11 12 13 14 15 16 17 18 19
20 21 22 23 26 27 28 29 30 31 32 33 34 35 36 37 38
44 45 46 52 53 54 55 56 57
76
95
114
133
139 140 141 142 143 144 145 146 147 148 152
171
174 175 176 177 178 179 180 181 182 183 184 185 186 187 190

organization and methods. The second year's operation showed a decrease of 55 per cent in the cost per acre over that of the first year; the season of 1922 has shown a dcrease of 62 per cent over the cost of the first year, notwithstanding expenditures on capital account, which in calculating the cost were put in as current expenditures. It is confidently believed that if aerial photographs were used to fill in the detail of the interior of the city blocks, the cost per acre could be brought down to a decrease of about 74 per cent from the first year's cost, or about $3.60 per acre. The accompanying progress map shows operations to date.

The drafting of the original sheets can be done more economically in the field than in the office. In the field the hours are longer and the draftsmen are working under a higher tension. Each field party is doing its best to increase its efficiency and the work of the draftsmen is designed to keep up with the field parties. Field notes that do not check can be examined upon the ground at once and any errors or omissions corrected. Draftsmen are also put to work on the field detail parties for a few days so as to be thoroughly familiar with field methods from personal experience.

The operations for 1922, Survey of London (F. P. Steers), are as follows:—

The engineer left Ottawa on May 25, with instructions to continue the survey of the city of London begun in 1920. On June 1 the assistant engineers arrived to take charge of their parties, the camp having been erected and everything ready for commencing work. A sectional hut was constructed and erected in camp, taking three men seven days. It proved very satisfactory and enabled the field draftsmen to plot three and a half sheets, comprising all the topographical details, except contours, of about 480 acres in the centre of the city. Owing to unforeseen and uncontrollable circumstances which shortened the season, two draftsmen who had the necessary qualifications for assistant engineers, were taken off drafting and put in charge of field detail parties.

The field parties double chained 3 miles of precise traverses, ran $3\frac{1}{2}$ miles of secondary levels, occupied 258 traverse stations, observing some 520 angles and surveyed by means of chained offsets from traverse lines all the topographical details, except contours, of some 1,382 acres of the most thickly settled part of the city. The contours of three sheets, comprising 413 acres, were also surveyed.

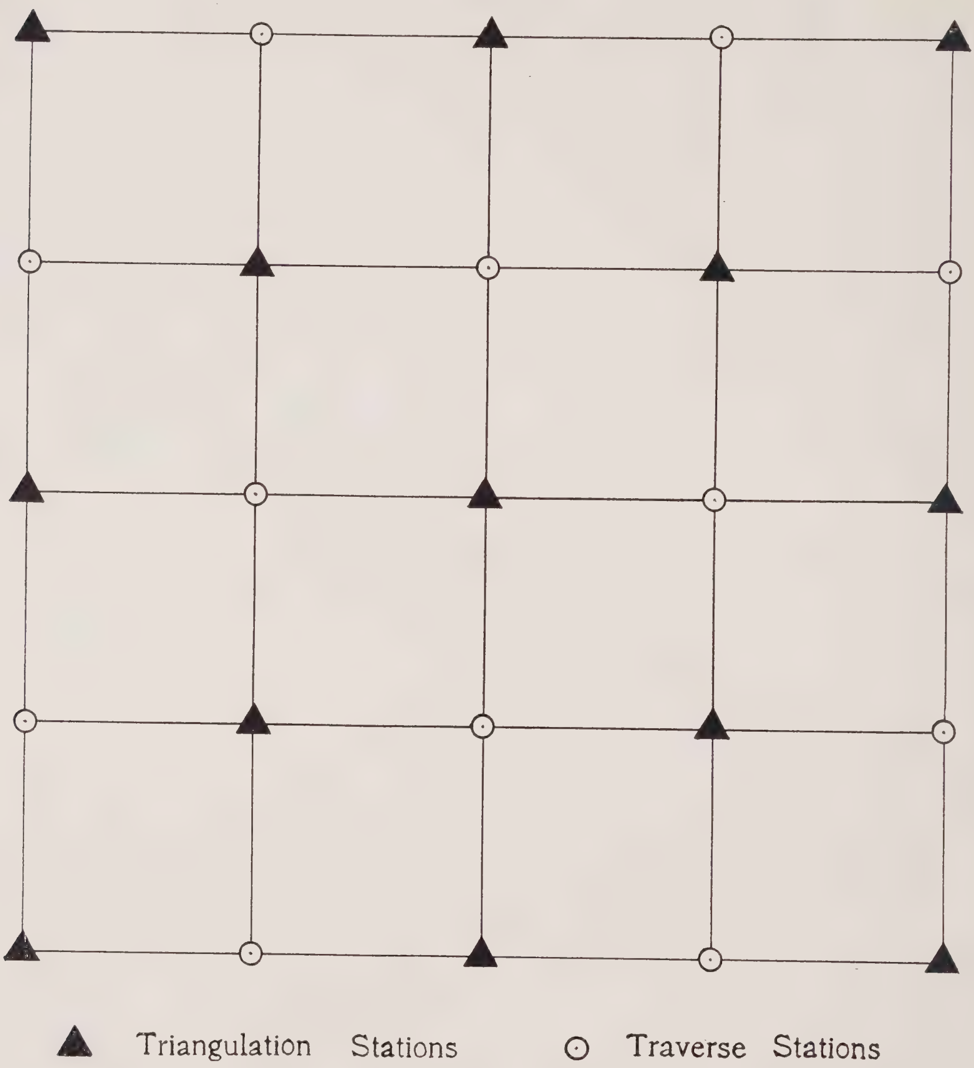
The area within the limits of the city of London is about 7,200 acres. It is proposed to publish sixty-eight sheets, each taking in 2,000 by 3,000 feet, which will cover this area; 2,068 acres have been surveyed and information necessary to show all topographical details, except contours, secured. To complete the survey of the city there is about 15 miles of traverses to be chained, levelled and observed, and 5,130 acres to be surveyed in detail.

The " Traverse Datum Line " of the traverse net of the city of London was chosen so that the X and Y axes, that is, the departure and latitude respectively of the traverse stations, should be parallel to the direction of the street lines.

During the adjustment of the traverse net it has been found that the measured lengths are of greater accuracy than the measured angles. To bring the angular values nearer in accuracy to the length values, it is recommended that the measurement of angles be made at night. This would result in less waiting for traffic to clear the line, less waiting for clear seeing, less strain upon the eye of the observer, less inaccuracy caused by refraction or boiling of the air when observing over sun heated pavements, thus giving greater accuracy while enabling faster progress to be made.

It is also recommended that bearing control stations be introducted as far apart as possible along main traverse courses. The bearing of lines between the bearing control stations would be first adjusted between triangulation stations and then the bearing of the intermediate courses adjusted between the bearing control stations.

In order to further improve the accuracy of the adjustment of a city traverse net, it is suggested that a city triangulation scheme should have stations placed as near to the positions as shown on this page, as the conditions will



City Triangulation. Scheme to improve the accuracy of the adjustment of a city Traverse Net.

permit. The stations are placed a mile and a half apart in lines which are three-quarters of a mile apart, every second line being staggered so as to bring the stations of the odd lines at a point opposite the midway distance between the stations of the even lines. It will thus be seen that thirteen stations will enclose an area of nine square miles, and that in extending the system, two extra stations would bring in three and a quarter square miles. In adjusting the traverse net to the triangulation net there would be a traverse station midway between two triangulation stations on an easterly main traverse line, which would also be a midway station on a northerly main traverse line. It is

suggested that if the position of the midway station were fixed in latitude and departure by the adjustment of the co-ordinates representing the length measurements of the right-angled main traverse lines it would be nearer to its true position than if angular values were used. The co-ordinates of the remaining traverse stations would then be adjusted between a triangulation station and the fixed traverse station in the usual manner. The position of the fixed traverse station adjusted in the manner suggested would be nearly as accurate as that of a triangulation station.

Mr. B. J. Woodruff spent the field season in charge of an angle measurement party of the survey of London. Upon his return to Ottawa he finished the measuring and calculation of the positions of the topographic control points for the balance of the Thirtyone Mile Lake watershed. During the rest of the time he was engaged in plotting the balance of the map and in putting material together for publication describing the field and office methods of stereophotogrammetric surveying.

Investigations and experiments have been continued in regard to the application of aerial photographs to map making and progress has been made towards working out a practical design for an " Aerophotoautograph " instrument.

Inspection of Reference Monuments in Ontario

(J. M. Riddell)

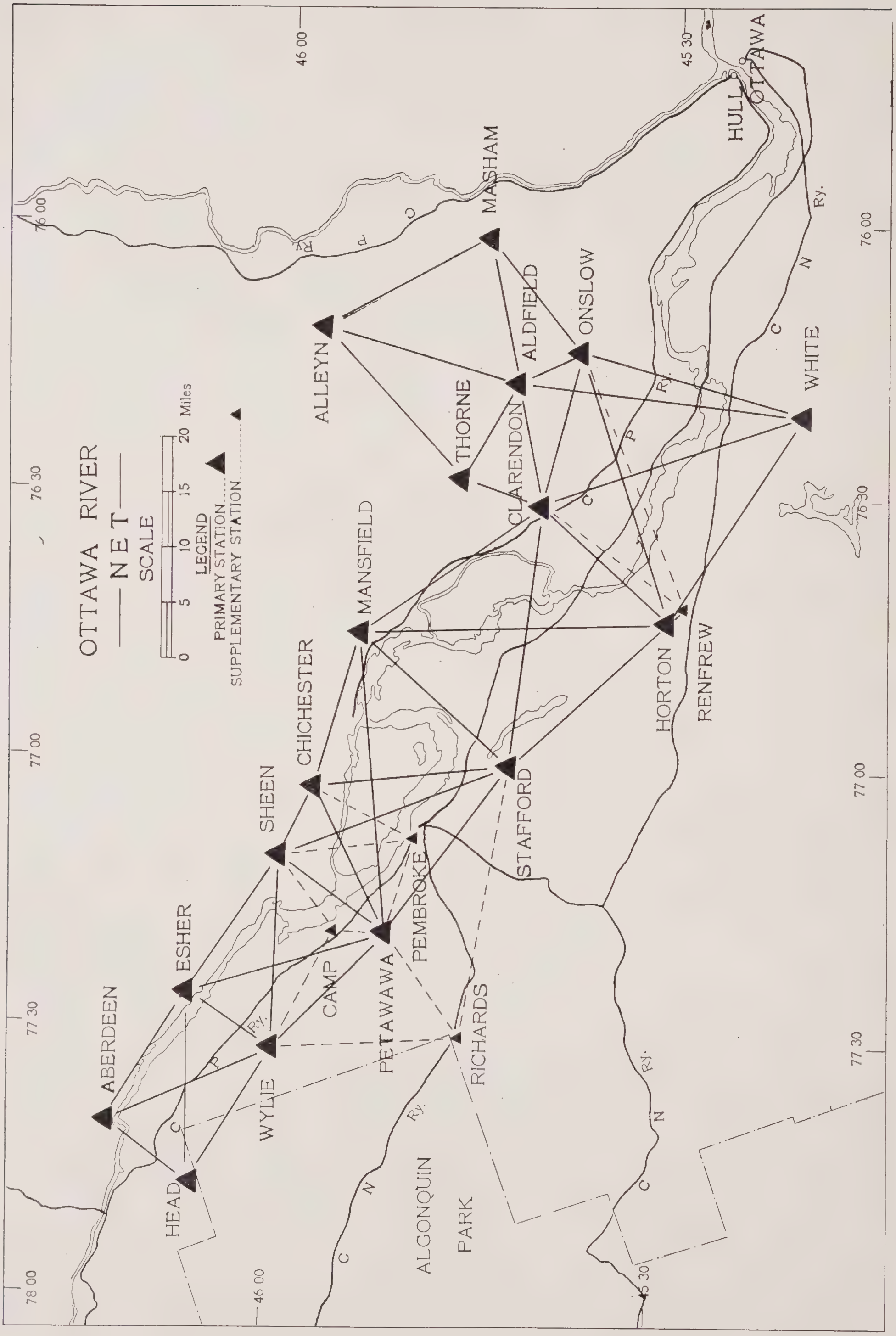
Instructions were given in April, 1922, that the various primary triangulation stations in Ontario at which reference monuments had been placed should be visited, to investigate the condition of these monuments and repair them where necessary. The distances and directions of these monuments from the geodetic stations were also to be checked and a tablet bearing information to the effect that the monuments were for Government survey purposes was to be placed in each.

A three-quarter -ton truck was used to transport the engineer and his helper and baggage, as well as a small outfit consisting of a three-inch transit, tapes, etc., for checking distances and directions; also an outfit consisting of shovels, tools, mixing-board and forms for the repair of broken monuments or the construction of new ones. A small amount of cement and gravel was also carried for repair purposes.

Over one hundred stations were visited and a great number of monuments were found to be partially destroyed due to the misguided efforts of the local inhabitants. New tops were placed on thirty monuments and six new standard monuments were built at stations, which were considered to have been insufficiently referenced before.

The method employed in placing new tops on monuments which had been broken at the base, consisted in drilling holes about six inches deep in the base at each of the four corners of the column and reinforcing the new column with rods of three-eights-inch iron, cemented into the base and extending about eight inches into the new top. All new tops were built twelve inches high and these should stand up better against the efforts of individuals to dislodge them. The fact of the monuments being identified now as survey monuments should also prevent to a great extent the vandalism of the past.

To accomplish this work between seven and eight thousand miles of the roads in Ontario had to be travelled with an average run of sixty-five miles per day. Ideal weather conditions prevailed practically the entire season; the time lost was only eight days.



OTTAWA RIVER
NET
SCALE
0 5 10 15 20 Miles
LEGEND
PRIMARY STATION
SUPPLEMENTARY STATION
ALLEYN
MASHAM
ALDFIELD
ONSLOW
THORNE
CLARENDON
WHITE
MANSFIELD
HORTON
RENFREW
CHICHESTER
STAFFORD
SHEEN
PEMBROKE
ESHER
CAMP
PETAWAWA
ABERDEEN
WYLIE
RICHARDS
HEAD
ALGONQUIN
PARK
HULL
OTTAWA
C P Ry.
C N Ry.
78 00
77 30
77 00
76 30
76 00
46 00
45 30

Primary Triangulation Reconnaissance Along the Ottawa River

(W. N. McGrath)

The engineer left Ottawa on May 8, with instructions to make a reconnaissance for the selection of primary triangulation stations of the wedge-shaped area between the Gatineau and Ottawa rivers, and then westerly along the Ottawa river. After an examination of the Gatineau scheme it was found that a line connecting the established stations, Alleyn and Masham, was most suitable for the extension of the triangulation westerly to the Ottawa river. From here the reconnaissance was carried up the Ottawa river as far as Des Joachims, a village on the Ottawa about forty-five miles west of Pembroke, where operations were suspended for the season.

In all, fifteen primary and three supplementary stations were selected. Supplementary stations established near the towns of Renfrew and Pembroke should be of value to the engineering departments of those towns and are visible from at least three stations in the main scheme. A supplementary station was established in the Petawawa military reserve at the request of the engineers of the Department of National Defence. A station was established at the southeast corner of Algonquin provincial park at the request of the Ontario Department of Lands and Forests.

The engineer spent a little time at the close of the season on Allumette island, investigating the possibilities of a base line, but on account of adverse weather conditions was unable to finish.

Extraordinarily wet weather, together with periods of low visibility, due mostly to large forest fires in northern Ontario, caused unusual delays to the work of this party all through the season.

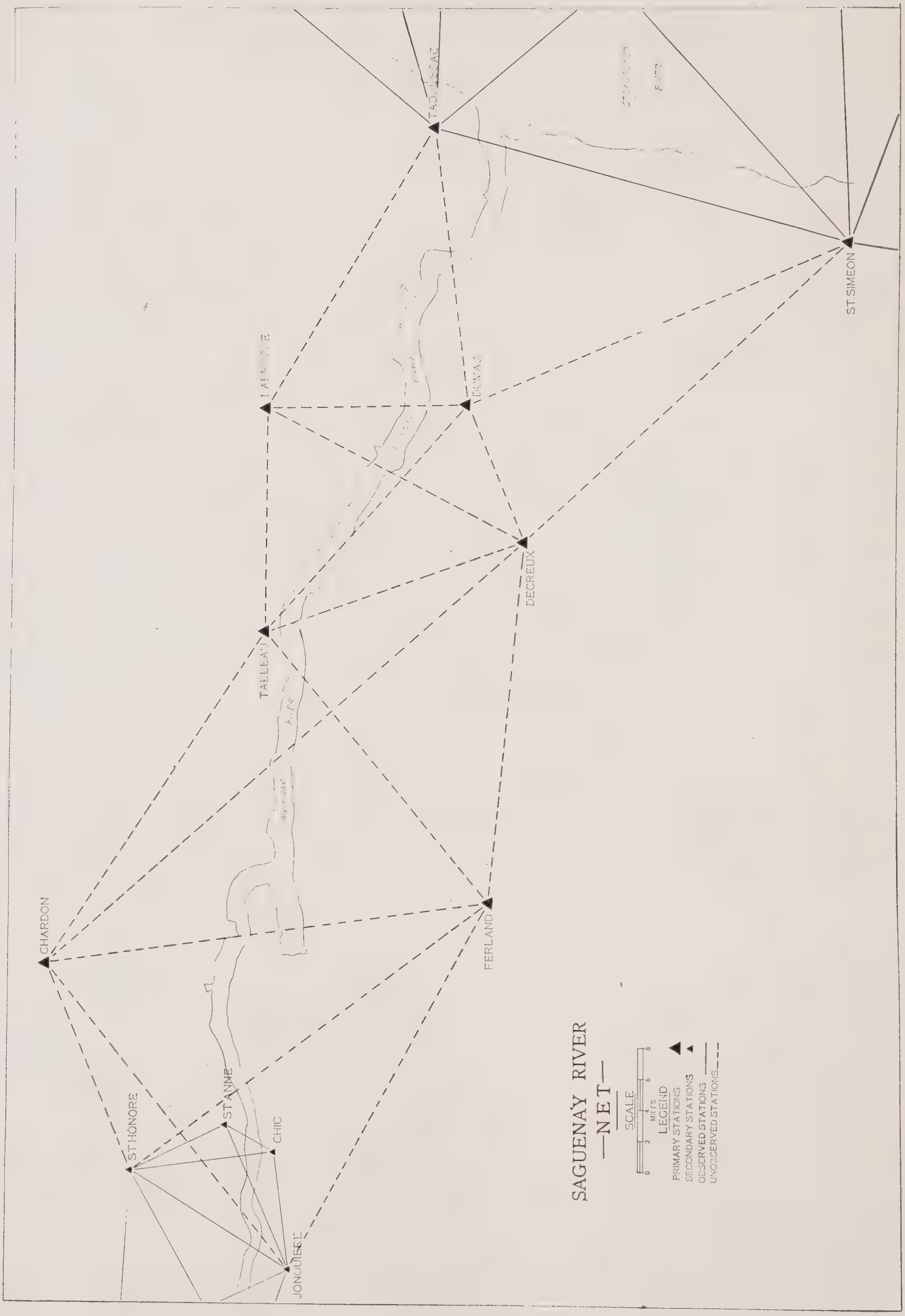
A brief summary of the season's work is as follows: Length of scheme in miles, 102; average width of scheme in miles, 16; area in square miles, 1,636; average length of primary lines, 17 miles; number of primary stations, 15; number of supplementary stations, 3.

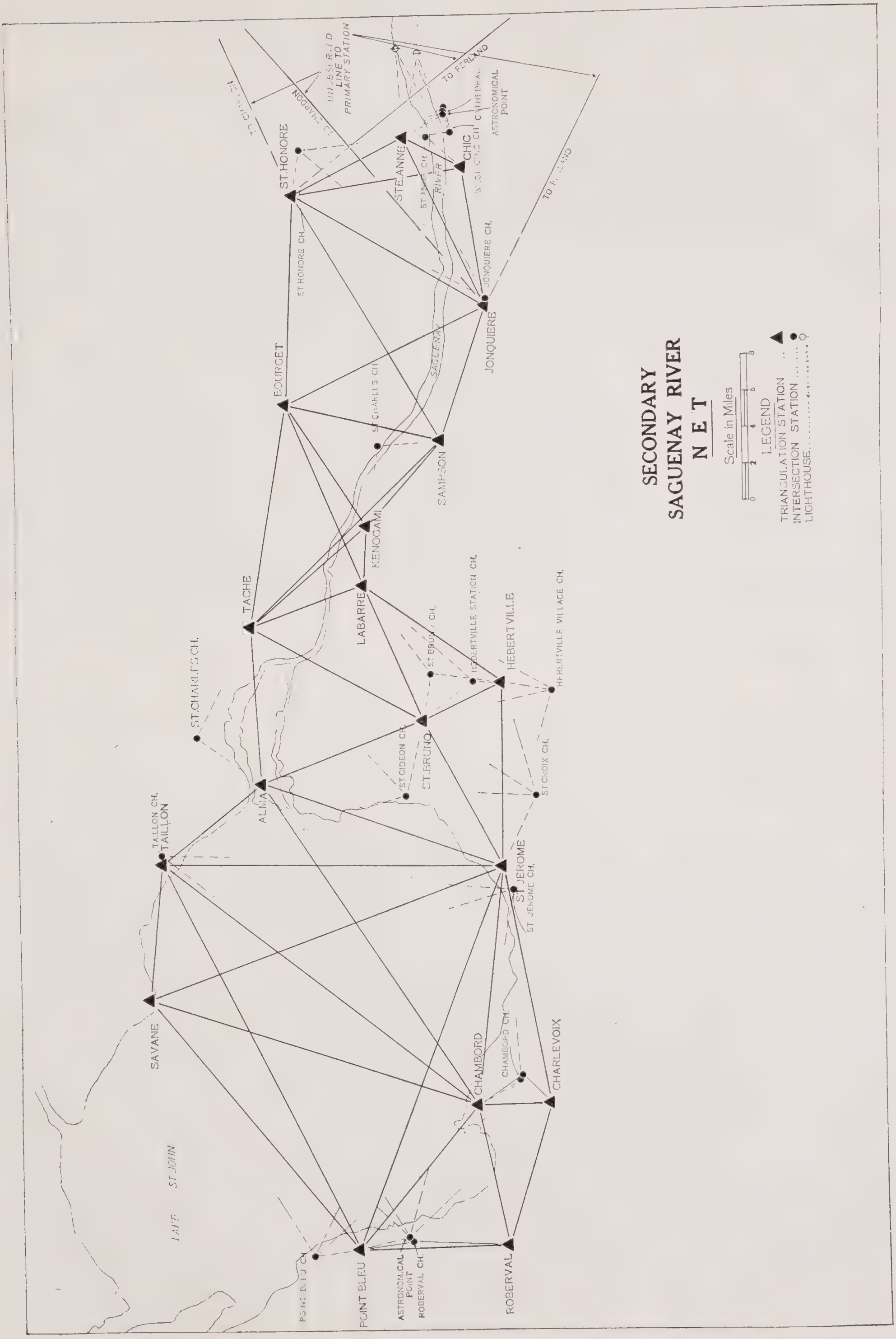
Secondary Triangulation on the Saguenay River, Quebec

(J. W. Menzies)

The engineer left Ottawa on May 8 with three men for the Saguenay river area, Quebec, to commence secondary triangulation in that area. After some preliminary reconnaissance of the primary triangulation of the lower Saguenay river, the engineer returned to Chicoutimi, set up camp and started work on extending the scheme by secondary triangulation along the Saguenay river as far as lake St. John. Two stations, Jonquiere and St. Honore, were first located, to step down from the primary scheme. From this line, Jonquiere-St. Honore, about ten miles long, the secondary triangulation was extended to lake St. John and then swung around so as to proceed south along the Quebec and Lake St. John railway. This part of the work was stopped on the line Roberval-Charlevoix. Observations were made at seventeen stations and the average length of line was 9·7 miles.

The astronomical piers at Chicoutimi and Roberval were tied in by triangulation and traverse. Connections were also made by traverse to three points along the railway between Chambord and Grand Baie. The Provincial Government has a precise traverse between these points and these connections are to be used as checks. Wherever possible church spires and other prominent objects were cut in.


ST.SIMEON
DECREUX
FERLAND
CHARDON
ST.HONORE
ST.ANNE
CHIC
JONQUIERE
SAGUENAY RIVER
—NET—
SCALE
0 2 4 6 8
MILES
LEGEND
PRIMARY STATIONS
SECONDARY STATIONS
OBSERVED STATIONS
UNOBSERVED STATIONS


SECONDARY
SAGUENAY RIVER
NET
Scale in Miles
LEGEND
TRIANGULATION STATION
INTERSECTION STATION
LIGHTHOUSE
ST. HONORE
ST. HONORE CH.
STE. ANNE
CHIC
JONQUIERE
JONQUIERE CH.
ASTRONOMICAL POINT
TO FERLAND
BOURGET
SAMPSON
SAGUENAY
RIVER
KENOGAMI
TACHE
LABARRE
HEBERTVILLE
HEBERTVILLE STATION CH.
ST. BRUNO
ST. CHARLES CH.
ST. GIDEON CH.
ST. CROIX CH.
ALMA
TAILLON CH.
TAILLON
ST. JEROME
ST. JEROME CH.
SAVANE
CHAMBORD
CHAMBORD CH.
CHARLEVOIX
ST. JOHN
POINT BLEU
ASTRONOMICAL POINT
ROBERVAL CH.
ROBERVAL

This party was disbanded on August 28 and a reduced party proceeded to the lower Saguenay to complete the revision of the reconnaissance for the primary scheme. Two new points were located.

Sketches showing the work accomplished are shown on pages 40 and 41.

Primary Triangulation of the Saguenay River, Lower St. Lawrence River and Gulf of St. Lawrence

(W. C. Murdie)

With the aid of the C.G.S. " Gulnare ", the parties in this area were distributed and ready for work by May 18, after a proper period of organization and training.

Work on the Saguenay.—The Saguenay river area was more or less difficult of access, there being very few roads, the best of which were little better than trails. Trails had to be cut and a great deal of preparatory work undertaken. The country, generally speaking, is quite rough, the slopes are steep with frequent rock outcrops presenting almost perpendicular faces with heights ranging up to over one thousand feet. It was necessary in many cases to approach the stations through narrow, steep valleys, or up steep draws filled by large angular boulders. The country is timbered except on the steep rocky slopes or where forest fires have devastated portions of the area.

Owing to unforeseen difficulties it could be clearly seen that the work would be considerably delayed, and on June 9 the entire party was transferred to the lower St. Lawrence. Later on during the season the secondary triangulation party operating on the upper Saguenay completed the work which was necessary to overcome the unforeseen difficulties, and everything is now in readiness for the return of the larger party at the commencement of the 1923 field season.

Work on the Lower St. Lawrence and Gulf Area.—The work on the lower St. Lawrence river and gulf area, generally speaking, progressed favourably.

Horses are required for Tower Building operations. This photograph shows the method of putting one ashore on the Gulf of St. Lawrence.

Landing Supplies and Survey Outfit at a Triangulation Station, Gulf of St. Lawrence.

Swampy plains behind Natashkwan on the north shore of the Gulf of St. Lawrence showing the difficulties of transport for triangulation operations.

When compared with the season of 1921 there was less fog, smoke and haze. Horizontal refraction came into play on several occasions, while abnormal vertical refraction was responsible for the completion of observations being taken over two of the longest lines across the St. Lawrence near the west end of Anticosti island.

South Shore.—The Gaspé coast is fairly high; there is a range of mountains running in an east and west direction in the centre of the Gaspé peninsula, forming the backbone of the area. The elevations near the west end of the county reach almost four thousand feet above sea level, while the maximum heights at the east end of Gaspé peninsula do not greatly exceed twelve hundred feet. Practically the whole area is wooded. Several fair sized rivers run northerly and empty into the St. Lawrence, while others flow easterly into Gaspé bay. The eastern portion of Gaspé peninsula is rolling with some parts suitable for farming.

North Shore.—The north shore of the gulf, east of the west end of Anticosti island, is very low along the coast, with a gradual increase in elevation as one goes inland. From the above mentioned point, islands increase in number as one travels eastward, and it is expected that some of these islands will be used as sites for the triangulation system. This will eliminate a great deal of man packing which would otherwise be necessary in order to reach inland stations. In the region within one hundred and fifty miles of the Labrador boundary, the coast is very broken and near the eastern end there are bays which resemble fiords. There are thousands of islands and reefs; these very frequently come abruptly out of the sea, there being deep water on all sides. The charts of the coast are old and incomplete, many islands are not shown and only a limited number of soundings are indicated. As a result it is not advisable for anyone not thoroughly acquainted with the coast to attempt to navigate a ship within several miles of it. Along the coast in the above mentioned area there are very few elevations exceeding five hundred feet, and, generally speaking, they are much less. Timber is scarce and existing trees are small. The country is bald and barren, with only small bushes or moss covering patches of the surface of the rocky hills. Among these hills there are a great many lakes and streams which provide excellent fishing.

Organization.—The parties operating on the Saguenay river, the lower St. Lawrence river and gulf area, were as follows:—

1. Engineer-in-charge with headquarters on C.G.S. " Gulnare ".
2. Two Direction Measuring parties, each comprising engineer-in-charge, one recorder, one lightkeeper, one cook.
3. Tower Building party, comprising engineer-in-charge, six carpenters or handymen, one cook.
4. Eight Lightkeeping parties, comprising lightkeeper-in-charge and helper.
5. Ship Party—C.G.S. "Gulnare" with a gross tonnage of 262, manned by six officers and eighteen other ranks, together with one wireless officer. One direction measuring party, under C. H. Ney, operated along the Gaspé coast, while the other, under J. H. Kihl, worked on the north shore and Anticosti island. C. K. McElroy superintended the erection of towers.

Equipment.—All land parties were equipped with electric signal lamps. As practically all members of the parties were qualified army signallers, a very efficient line of communication was maintained between the engineer-in-charge on the " Gulnare " and all parties, by the combined use of signalling with lamps, land telegraph lines and wireless.

Results.—As a result of the season's operations the triangulation net in the lower St. Lawrence area was extended eastward from the line joining Thunder

River village on the north shore, and St. Antoine village on the south shore, to cover an area of approximately 6,000 square miles.

The following results were obtained: Directions on primary stations completed, 53; secondary directions completed, 2; directions on lighthouses completed, 20; directions on churches completed, 6; concrete piers constructed, 13.

Closing of Season.—It was found necessary to close up operations earlier than had been originally planned. The tower building party left the field on September 5, while the parties connected with angle measuring were disbanded on September 11. The " Gulnare " proceeded direct to Halifax, where everything was put in order to be laid up for the winter.

Triangulation Reconnaissance on the Gulf of St. Lawrence

(H. G. Rose)

The reconnaissance survey for locating the stations of the primary triangulation scheme on the gulf of St. Lawrence during the season of 1922 consisted of two parts:

(*a*) On the bay of Chaleur a triangulation scheme was to be laid down, connecting the present reconnaissance of the St. Lawrence river, which had been located as far as Gaspé, with the New Brunswick triangulation, which ended just south of the bay of Chaleur.

(*b*) On the north shore of the gulf of St. Lawrence the triangulation was to be extended from the end of the 1921 reconnaissance operations.

The party, which consisted of the engineer and one assistant, started operations on May 8. By the end of July the reconnaissance along the bay of Chaleur was completed, a distance of approximately 150 miles. During August the party was engaged in similar work on the north shore, from Watshishu to Natashkwan, a distance of approximately 50 miles being covered.

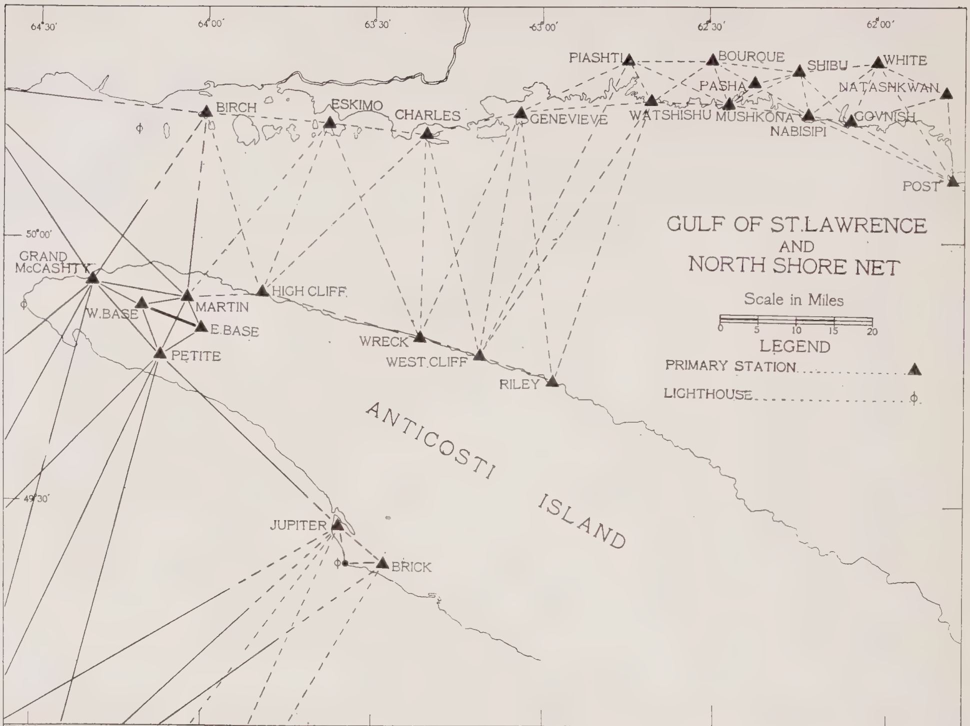
The north shore of the bay of Chaleur is very high and rugged, the hills within three or four miles of the bay being as high as 1,900 feet. At the east end of the south shore, in the vicinity of Miscou and Shippigan islands, the country is very low and flat with scrubby bush. The land rises near Bathurst, N.B., and at Campbellton the hills are more than 1,000 feet high. There are many prominent church spires and lighthouses on both sides of the bay of Chaleur which may be cut in from the triangulation stations.

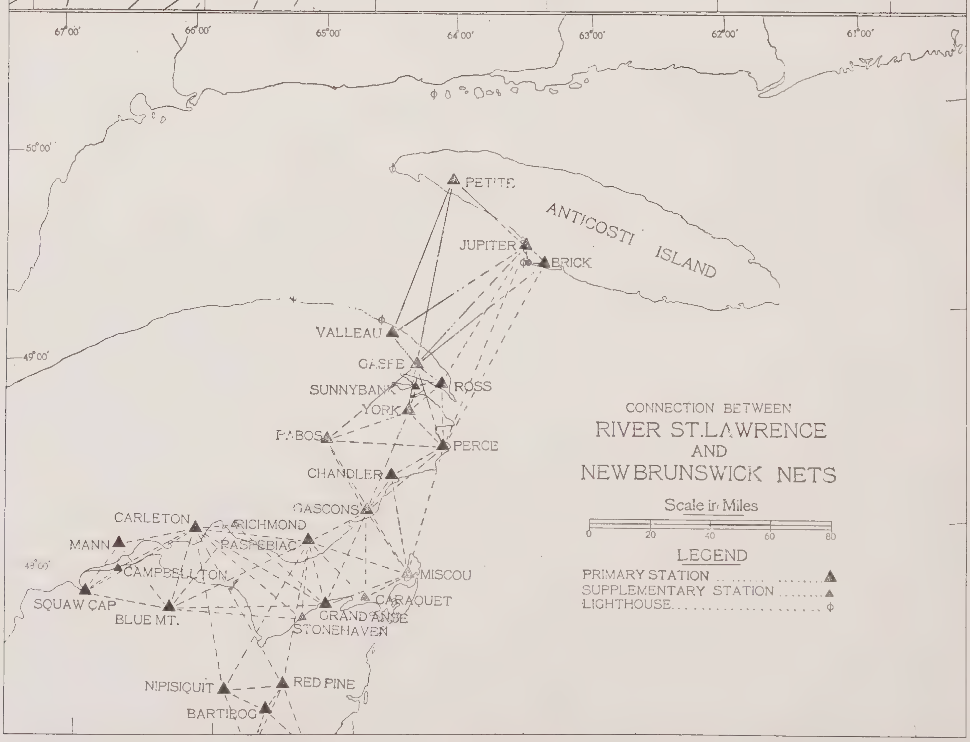
Considerable difficulty was experienced in locating a triangulation net around the corner of Gaspé peninsula at Percé, as an accessible inland station, about thirty miles back from the shore, was required to obtain a strong figure, and there are no settlements inland. A station, " Pabos," was finally located on a hill on the timber limits of the Chicoutimi Pulp Company, which has a mill at Chandler. The company has made a fine map of their limits in order to locate the timber. Transportation for getting into the hill was obtained by means of one of the company's portage roads.

Eleven primary and five supplementary stations were chosen on the bay of Chaleur (see sketch on page 46).

By August 1 the work on the bay of Chaleur was completed and the party crossed to the north shore on the C.G.S. " Gulnare ", arriving at Watshishu August 3.

In 1921 the triangulation had been carried along both sides of the channel north of Anticosti island, as far as Charleton point on Anticosti island and Watshishu on the north shore. At this point the country on the north shore was getting quite low, hills of 150 feet in height being rather the exception. It was, hence, impossible to continue bridging the channel between Anticosti and the north shore on account of the low lying country, and the triangulation had to be carried entirely along the north shore.


GULF OF ST.LAWRENCE
AND
NORTH SHORE NET
Scale in Miles
0 5 10 15 20
LEGEND
PRIMARY STATION
LIGHTHOUSE
ANTICOSTI
ISLAND
PIASHTI
BOURQUE
SHIBU
WHITE
PASHA
NATASHKWAN
BIRCH
ESKIMO
CHARLES
GENEVIEVE
WATSHISHU
MUSHKONA
NABISIPI
COVNISH
POST
GRAND
McCASHTY
HIGH CLIFF
MARTIN
W.BASE
E.BASE
PETITE
WRECK
WEST CLIFF
RILEY
JUPITER
BRICK
64°30′
64°00′
63°30′
63°00′
62°30′
62°00′
50°00′
49°30′


CONNECTION BETWEEN
RIVER ST.LAWRENCE
AND
NEWBRUNSWICK NETS
Scale in Miles
0 20 40 60 80
LEGEND
PRIMARY STATION
SUPPLEMENTARY STATION
LIGHTHOUSE
ANTICOSTI
ISLAND
PETITE
JUPITER
BRICK
VALLEAU
GASPE
SUNNYBANK
ROSS
YORK
PABOS
PERCE
CHANDLER
GASCONS
CARLETON
RICHMOND
MANN
PASPEBIAC
CAMPBELLTON
MISCOU
SQUAW CAP
BLUE MT.
CARAQUET
GRAND ANSE
STONEHAVEN
NIPISIQUIT
RED PINE
BARTIBOG
67°00′
66°00′
65°00′
64°00′
63°00′
62°00′
61°00′
50°00′
49°00′
48°00′

On account of the difficulty of access to the interior of the country it was deemed inadvisable to attempt long lines with the consequent inordinate transportation expense in the instrumental occupation of the stations far inland. It was, hence, decided that the most economical plan was to locate a scheme with stations fairly close together, which would still permit of the accuracy required for primary triangulation.

Beginning at the line Genevieve to Watshishu, a triangulation scheme with short sides, from 6 to 10 miles long, was located along the shore as far east as Natashkwan (see sketch on page 46). The plan followed was to keep one series of stations along the shore and another series inland six miles or more.

The inland stations were chosen as close to rivers as possible, to facilitate transportation by canoes, as packing by land is difficult, the ground being so rough and broken with muskeg and swamps.

Eight stations were chosen on the north shore. On account of the flat nature of the country, the only way to be certain of the identification of some stations was to put up signals which were visible with the short lines. The bushy top of a small tree with a white cotton flag nailed underneath made a very good signal when properly braced and anchored with stones and did not involve much labour in carrying of material.

There is no difficulty in transportation along the shore, which is very broken with small islands and reefs. A motor-boat drawing two or three feet can pass by inside passages for miles and go into all the inlets at high water. There are small settlements along the coast, the inhabitants of which make their living by fishing and hunting. Two steamers give a weekly service during the summer along the north shore of the gulf of St. Lawrence, as far as Natashkwan, and a service is provided every two weeks to Bras d'Or bay, near the boundary between Canada and Labrador.

The land is very bare and is composed chiefly of rounded granite rock, though in a few places there is sand which forms large dunes, notably in the vicinity of Natashkwan. There are large areas of swamp and swampy lakes, and plains covered with "Labrador Tea." The country seems to be almost one-quarter water, considering all the lakes and ponds through the muskegs.

There is good wood in some of the valleys along the banks of the rivers. In the case of the one tower which is necessary, the wood will have to be cut up the river and driven about two miles. Some photographic work is being done on the Natashkwan river, one of the longest rivers on the coast, to determine what timber limits are available above.

Reconnaissance for Primary Triangulation on Cape Breton Island, Nova Scotia

(H. P. Moulton)

The season's operations consisted chiefly in the completion of the Cape Breton reconnaissance from Baddeck to St. Paul island, and the connection with Newfoundland. Stations were selected on cape Smoky and Money point as giving the most suitable base for the Newfoundland connection; the task of filling in between this line and the work of 1921 was accomplished with considerable difficulty on account of the configuration of the country and very unseasonable weather.

The northern part of Cape Breton is picturesque but very rough and rugged. The road closely follows the coast line as far as bay St. Lawrence. The mountains rise almost precipitously from a narrow beach to heights of 1,100 to 1,400 feet, while the height of land is about 15 miles inland with an elevation of 1,500 to 1,600 feet; the intervening country is broken by deep ravines and watercourses, leaving innumerable small ridges which are of nearly equal elevation. Most of the country is thickly wooded; the timber rights are held by the Oxford Paper Company.

Twelve stations were required to cover this area. Three of them were ground stations and the others required towers from 13 to 70 feet in height. The stations near the coast are quite easily reached, but it was difficult to obtain interior stations which would maintain the desired strength of figure and yet be accessible with reasonable cost.

Station Norman is located on the Oxford Paper Company's limits, about 16 miles from their mill at Murray. This station required a 70-foot tower to clear an intervening ridge to station "Wreck." The company's officials were very courteous and were pleased to have this tower on their limits as an aid to fire detection. They supplied transportation for the building party and helped the engineer on many occasions. Two stations were located on what is known locally as the "Big Barren," near the headwaters of the Cheticamp river.

From five exterior stations it will be possible to obtain intersections on practically all the churches and lighthouses on the northeast coast.

In October two stations were located in Newfoundland, one near cape Ray and the other at cape Anguille. These stations are sufficient to establish the positions of Anguille and cape Ray lighthouses, which are maintained by the Canadian Government.

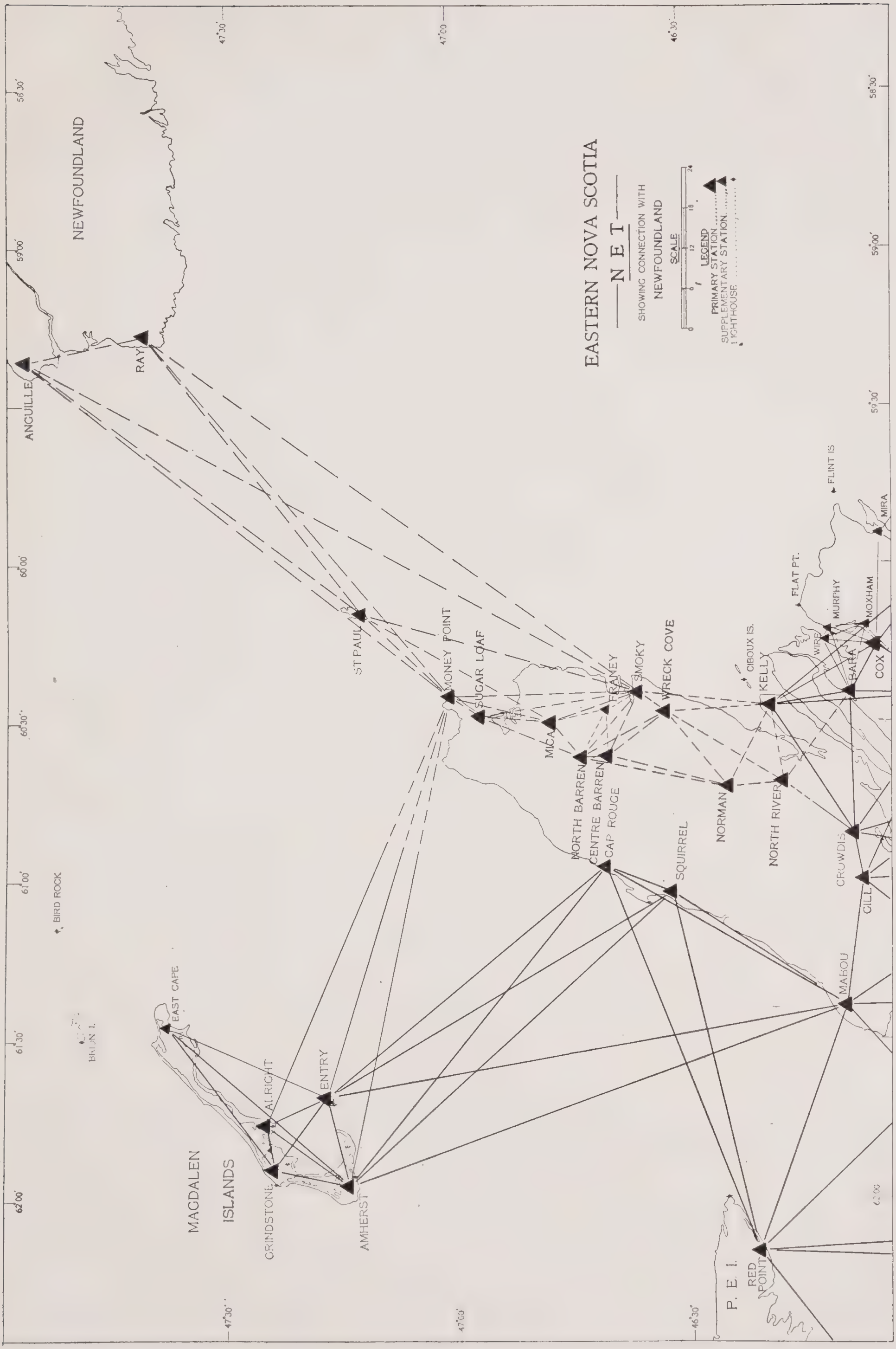
The average height of the fourteen stations is 1,270 feet, average elevation of towers 35 feet; longest line in Newfoundland connection is 102 miles.

Direction Measurement and Tower-building Operations in Nova Scotia

(J. E. R. Ross)

The main objective of the direction measurement parties was to connect Magdalen islands by triangulation to Cape Breton. The points occupied on the islands were four in number and coincident with the Hydrographic Survey stations on the summits of Entry, Amherst, Grindstone and Alright islands. They were connected with three points on the northwest coast of Cape Breton at Cape Rouge, Grand Etang and Cape Mabou, the first two being established from the line Red Point-Cape Mabou of the previous season's work.

As many of the connecting lines are from 70 to 80 miles in length, with elevations of 1,200 and 500 feet at the Cape Breton and Magdalen ends respectively, the lines of sight for quite a portion of the length lay very close to the water surface. Under these conditions it was naturally expected that abnormal refraction would be noticed. Such turned out to be the case, but was most marked in a vertical plane, the movement in a horizontal plane affecting only a few of the readings. On the line Amherst to Cape Mabou, both engineers, with the exception of one night, were compelled to take readings on the image of the electric light when it appeared as a vertical pencil of light about twenty seconds of arc wide and approximately twenty minutes of arc high. Several variations of the refraction as indicated by the image were noticed. Among them occurred a vertical line of disks, uniform in size, sometimes clear cut and separate; at other times overlapping all of the same colour, namely, white or yellow; other times the image would consist of three distinct disks, each coloured as follows: red above, white in centre, green below, or vice versa. In all of these cases the images would be in a vertical plane and observations for horizontal angles were not delayed, the results being quite satisfactory. The change from one phase to another would take place every few minutes, but generally the conditions would be maintained for an hour or more. All of these conditions were noted shortly after sundown and when there was very little wind. The maximum number of disks noted at one time was seven and occurred at Amherst on this same line. It may be noted that curious effects have been seen also with the acetylene lights such as flares, dumb bells, etc., but the disk formation seems to be peculiar to this area.


EASTERN NOVA SCOTIA
N E T
SHOWING CONNECTION WITH
NEWFOUNDLAND
SCALE
LEGEND
PRIMARY STATION
SUPPLEMENTARY STATION
LIGHTHOUSE
NEWFOUNDLAND
ANGUILLE
RAY
ST PAUL
MONEY POINT
SUGAR LOAF
FRANEY
SMOKY
WRECK COVE
MICA
NORTH BARREN
CENTRE BARREN
CAP ROUGE
NORMAN
NORTH RIVER
KELLY
CIBOUX IS.
FLAT PT.
FLINT IS
MIRA
MURPHY
MOXHAM
WIRE
BARA
COX
CROWDIS
GILL
SQUIRREL
MABOU
BIRD ROCK
EAST CAPE
MAGDALEN
ISLANDS
ALRIGHT
ENTRY
GRINDSTONE
AMHERST
P. E. I.
RED
POINT

In marked contrast to the previous season, during which the weather was exceptionally favourable for rapid prosecuiton of the work, the operations in 1922 were seriously delayed by long periods of rain and fog. In all, about 60 per cent of the nights were useless for observing purposes.

As in previous years, a double observing party was employed, the sub-parties being in charge of C. H. Brabazon and L. N. Wadlin. The former occupied all of the stations on the Magdalen islands and the latter those on the northwest coast of Cape Breton, as well as a small scheme necessary to establish a primary control point, Kempt, on the western end of Boularderie island.

A summary of the observing is as follows: Primary stations established, 7; primary stations reoccupied, 5 (formerly established); secondary stations established, 1.

The number of lighthouses, churches, etc., with three or more intersections, or a complete check on their final position, is as follows:—

Brion Island lighthouse, Entry Island lighthouse; Roman Catholic churches on islands Alright, Grindstone (La Verniere), and Amherst (Havre Aubert and Basin); Church of England on Entry island and wireless mast on Grindstone island.

The station preparation for the above work was completed in 1921. Tower building operations were confined to the east coast of Cape Breton on the extension of the main net to cape North and Newfoundland. N. E. Kelly was again employed as tower builder.

The north country of Cape Breton is very rugged and tower building operations were conducted under exceptional difficulties. Only one road is available and that along the coast. The hills rise abruptly to an elevation of 1,200 to 1,400 feet and are separated by deep river ravines. On the summits the timber is very thick in places and in other places the scrub is so thick that trails had to be cut to get in the equipment. Owing to these circumstances and the poor weather conditions, the work accomplished is considerably less than last year.

Eight towers with an average height of 35 feet were erected during the season. These towers complete the stations required for the connection with Newfoundland. Before moving to another territory, it is intended to employ this party a short time during the season of 1923 in placing more conspicuous marks at some of the stations in Cape Breton. The reasons for these markings may briefly be summarized in the statement that the dense underbrush and bog vegetation may in a very short time completely cover the disk bolts used for station marks on surface rocks and make the recovery of the station extremely difficult or even impossible. Concrete piers will be used in remarking these stations.

Selection and Measurement of Base Lines at Oyster Bay and Yellowhead Pass

(K. H. Robb)

Accompanied by one assistant, the engineer left Ottawa on May 19 with instructions to proceed to Courtenay, B.C., for the purpose of making a reconnaissance for the selection of a base line and its connection to the main triangulation scheme along the British Columbia coast. On May 25 a number of prospective sites were visited. Later at Oyster bay a better prospect was found.

Oyster bay is about three miles across and has wide tide flats, which would afford opportunities of crossing at low tide. A careful examination of the country north and south of the bay showed a base about four and a-half miles could be placed in this locality. The south end of the base was finally located on a gravel bed near Kuhkushan point, and the line was projected in a northwest direction to a point on the south shore of Oyster bay, across the bay

to its north shore and to a point about a mile distant from the shore of the bay and about a mile behind Shelter point. At this point (north base) a tower about forty feet high was necessary for sighting above the surrounding timber. In order to measure across the bay, two deflections were made in the base, one near the south shore of Oyster bay and the second near the north shore. The angles of deflection were approximately fourteen and twelve degrees respectively. Putting in the deflection angles and crossing the bay in this way saved the cutting of much heavy timber, for otherwise the line would have been located practically a half mile inland where forest was present.

The connection of the base line to the primary triangulation was effected by the introduction of two new triangulation stations, Mitlenatch and Read island besides the north and south ends of the base.

On June 16 preparation of the base line was commenced. About one-and-a-half kilometres of the line was covered with a fairly heavy forest, more than four kilometres was across the tide flats, and the remaining section of nearly two kilometres was across farm land or clearing. Concrete piers were placed at the ends of the base, also at the three deflection points. The ends of the base and the deflection points were marked by the centres of the small holes on the tops of copper bolts which were imbedded in the concrete. The base was posted in the usual way starting from the south base. Posts four by four inches were driven on line every fifty metres and smaller ones just off line at intermediate intervals. In some sections of the base crossing the tide flats it was impossible to drive posts on account of the rock. Here, key posts loaded with stone proved most satisfactory. The tide had little or no effect on the posts driven into the sand; each tide seemed to wash sand around the posts making them more solid. Of course, all the work across these tide flats had to be carried on at low water, but otherwise conditions were nearly perfect. Levels were run over the tops of the posts to determine the elevations, and the deflection angles at the three turning points were measured with a twelve-inch theodolite.

The average elevation above mean sea-level was only four metres, and the grades were in most cases very small. The method of measurements has been described in detail in the report of the measurement of the Fort Rupert base. The length of the base, corrected for deflections, grade and height above sea-level is 7,156·610992 metres.

After the completion of the measurement on July 23 three of the party were discharged and the remainder were employed for three weeks in clearing lines and building a 40-foot tower at north base and a 15-foot tower at south base. There was considerable line cutting at north base in order to get clear vistas to the several triangulation points. The work was finally completed on August 15 and the party discharged.

From the day of starting the reconnaissance till the work was finished there was not a single shower of rain sufficient to stop operations.

Yellowhead Pass Base Line at Lucerne, B.C.—On January 12, 1923, the work of preparation for the measurement of the Yellowhead Pass base line was commenced. The rough nature of the country made it necessary that the base line run down the centre of Yellowhead lake and that the work be done when the lake was frozen over.

A concrete pier was first built over the geodetic station at the east end of the lake, and starting from this point the posts were set in the ice at the usual 50-metre intervals. This was done by cutting holes to a depth of 10 inches and putting the posts in position and then packing snow and water around them and leaving them over night to freeze. The posts when thus frozen in were very solid and no difficulty was experienced from their shifting.

Projections of the land towards the middle of the lake enabled the base to be divided into four sections, the first of thirty-eighth, the second of thirty-

eighth, the third of twenty-six and the fourth of fourteen 50-metre lengths. At the end of each of these spaces permanent turning points were placed, thus eliminating any chances of the posts being disturbed through heaving of the ice.

In order to avoid the open water at the narrows near the west end of the lake it was necessary to deflect the line at post 102. The deflection angle is only 6° 18′ and at this point (post 102) a concrete pier was built and a copper bolt imbedded in the concrete. At West Base also a concrete pier was built; this pier was 23 inches by 27 inches on top and 7 feet deep, 3 feet being above ground. Below the surface of the ground the pier is 4 feet by 4 feet and the bottom is below the frost line.

Measurements were carried on when weather would permit, as the thermometers would only register 2 degrees below zero Fahrenheit. During the work some very cold weather was experienced as the temperature went as low as 32 degrees below zero. Levels were run over the posts to determine the elevations and connected with the precise levels of the Geodetic Survey of Canada. The same methods as used on all primary base lines of the Geodetic Survey were used. The work was completed on February 10 and the party discharged.

Standards and Geodetic Astronomy

(F. A. McDiarmid, Supervisor of Standards)

STANDARDS

Base Line Tapes.—The fifty-metre invar base line tapes of the Geodetic Survey of Canada were standardized in May and September before and after measuring the Oyster Bay base line, also in December and February, before and after measuring the Yellowhead Pass base line. Professor Glazebrook of the Physical Laboratory at Teddington, England, some years ago said that he had never seen an invar tape that followed any fixed law in its lengthening or shortening, and emphasized the constant need of referring constantly to some standard. The practice in the Geodetic Survey of Canada is to refer the base line tapes to the standard metre bar No. 10239. This process has been fully explained in a publication of this Survey entitled "Standardization of Base Line Tapes from the Standard Nickel Bar No. 10239". One of the Geodetic Survey tapes No. 4252, which has been always kept as a reference tape, shows a slight lengthening of about thirty microns in 1922 over its length in 1921, or about one part in 1,700,000. Of the three field tapes Nos. 3139, 3140 and 3141, No. 3139 is shorter by 68 microns; No. 3140 is shorter by 18 microns, and No. 3141 is longer by 11 microns than in 1921. Between May and September, 1922, No. 3139 had increased 51 microns; No. 3140 had decreased 26 microns, and No. 3141 had decreased 2 microns in length. These results confirm Professor Glazebrook's statement. In addition to the fifty-metre tapes there were standardized two twenty-five metre invar tapes and several hundred-foot tapes used in city triangulation.

Precise Level Rods.—The series of observations commenced in the spring of 1921 on the six pairs of precise level rods of the Survey was continued throughout the past season. The rods were standardized in the spring before going to the field, at intervals throughout the summer and again in the fall at the close of the field season. The changes of length in these several rods were in some cases quite appreciable. Only one example will be given here. The change in the length of one pair of rods would have introduced an error of ·333 foot in the difference of elevation between Winnipeg and Calgary. Full details of these observations for the years 1921 and 1922 will be given in a separate report. Humidity increases the length of the rods and the lack of moisture shortens them.

Reference was made in the last annual report to the desirability of attaching invar strips to the rods to carry the graduations. These invar strips have been prepared and are being graduated.

GEODETIC ASTRONOMY

Two of the triangulation stations in the British Columbia net were occupied as Laplace stations, Little Mountain near Vancouver and Cape Lazo on the east coast of Vancouver island. Before and after the field observations the relative personal equation between the field astronomer and Riefler clock of the Dominion Observatory was determined from eleven nights observations.

The base for all Canadian longitudes is the meridian circle pier of the Observatory transit house. The great advantage in co-operating with the Observatory in longitude work is that the Riefler clock with its nearly perfect rate is available for longitude determinations. For some years past the various determinations of differences of longitude at a station have shown a very close agreement; in most cases the range of differences obtained in five nights does not exceed five hundredths of a second. At Little Mountain the range of the differences of longitude was only ·029 second and at Cape Lazo the range was ·042 second. This increased accuracy is due in part to the constant rate of the Riefler clock, and to the greater experience of the field astronomer. In all kinds of precise observations the training of the observer is most essential, and it is only after years of careful observing that consistent results are obtained. Reference has already been made to personal equation observations. The relative personal equation between the field astronomer and the Riefler clock in 1921 was ·060 second of time and in 1922 ·061 second; the field astronomer in each case anticipating the Riefler clock. These observations, year after year, always about the same, show that with the astronomical transit as used by the Canadian observers there is personal equation of tangible size.

Adjustments and Geodetic Research

(W. M. Tobey, Senior Geodetic Engineer)

The work of the adjusting office comprises two general classes of work:—

(*a*) Special or research work, including new theory and methods of calculations, and

(*b*) General work in connection with the adjustment of triangulation and level nets.

Special or research work is continuously required to cope with new problems and to improve methods previously in use; during the year 1922-23 its importance and necessity have been emphasized. New methods have been developed for calculation and adjustment of precise traverse lines. These lines consist of a large number of measured courses and angles, and it was felt that the methods of calculation of the positions of the angular points of the traverse as well as the adjustment of the traverse between fixed triangulation stations merited special investigation.

By the methods evolved the calculations of the traverse could be made as on a plane, that is latitudes and departures of the courses would be calculated, with corrections to be applied to reduce them to the ellipsoid. The reduction gave the polar distances (distances from an initial station to each other station on the traverse) the same as on the ellipsoid. Corrections must be applied to the plane latitudes, departures and azimuths depending on the spherical excess of the polar triangles (triangles radiating from the initial to points on the traverse). This method of calculation is fairly simple and promises close approximation to the truth even for very long traverses.

In triangulation systems the angles only are measured and, hence, an adjustment of the angles only is made. With a precise traverse both angles and distances are measured, so that a rigorous adjustment of a traverse requires correc-

tions on both measured angles and measured lengths. *The provision of simultaneous corrections to quantities so mathematically different as angles and lengths was a difficult problem which it is believed has been successfully solved.* In the method of adjustment worked out the distance and azimuth from the fixed triangulation station considered as the initial to other similarly fixed stations are calculated on the spheroid and afterwards transformed to reduce them to the plane. These are, hence, polar distances (explained above) which give conditions which the adjustment must achieve.

The differential method of adjustment, which has recently been inaugurated in connection with the adjustment of level nets, has lately been applied to the adjustment of triangulation nets. By the application of this method new field data, whether of large or small amount, can be easily incorporated with previous adjustments.

The general work of the adjusting office is summarized under the following heads:

1. Analysis of Field Results.
2. Furnishing Adjusted Data.
3. Adjustments of triangulation and level nets.
4. Determination of the precisions or probable accuracy of various parts of the triangulation and level nets as advisory for new field work.

Analysis of Field Results.—During the past year the usual inspection of accuracy of field work was done by analysing the work submitted. No serious accumulative errors were found. This analysis of field work of all the parties is a fundamental way of obtaining a working knowledge of the extent of the accumulation of errors running through the work and of finding the probable precisions of external parts of the triangulation and of the levelling systems. An accumulation that is beyond the regular limits must be corrected by having some change made of the field structure. Any change in field work which the adjusting office may find necessary must always be considered in relation to its amalgamation with the old work and in the effect of this amalgamation on distant parts of the work.

Analysis of the field results of the triangulation, which in a preliminary sense is accomplished by an examination of the individual engineer's work at each station, is in a fuller sense consummated by an examination of how the work fits together as a whole. Only by keeping field errors within narrow limits can troublesome accumulation of these errors be prevented. To this end the angle and side equations are tested to see if they are of the required accuracy, the side equation test for primary triangulation being that the average correction to a direction given by the adjustment should not be greater than $0''{\cdot}4$. Secondary work was examined by similar methods. Preliminary tests are naturally performed by the field men but the final check is made in the office.

The differential adjustment of observations has afforded an invaluable means of locating errors not disclosed by preliminary tests. Especially in the case of the British Columbia work has this analysis by the differential adjustment method been of the greatest value.

The analysis for accumulative error is seen to be most important from the fact that all present nets must be built up on nets previously established, which are themselves affected by all errors or weaknesses which have gradually accumulated throughout the previous work.

During the year many descriptions of triangulation stations have been received and revised. These are essential to the recovery of stations.

Furnishing Adjusted Data.—Generally requests for data arose from the different federal departments, the provincial departments and private engineering firms. The federal departments supplied with such data were the National Defence, Public Works, Geographer's Branch of the Interior Department, Topo-

graphical Surveys Branch of the Interior Department, International Boundary Commission of the Interior Department and the Geological Survey. Information was also supplied to a number of the surveying and other organizations of Provincial Governments, engineers of various cities and to many private engineers.

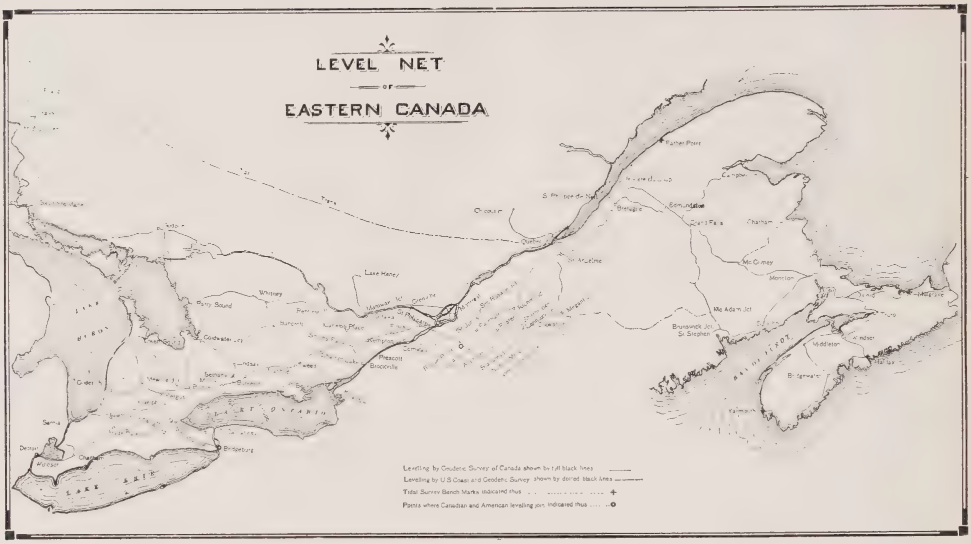
Mention might also be made of the work prepared for the International Union of Geodesy and Geophysics held in Rome during May, 1922. For this conference a great deal of material (triangulation and level results) was collected and a description of methods of adjustment in each case given. Precisions of the results and of different parts, always so necessary for a basis of comparison of the accuracy of the work as a whole, were also collected; these precisions including not only those for different parts of a complex interwoven system of the adjustments, but also including the cases of all the measured bases and of the azimuths and longitudes of the work entering into the Laplace results.

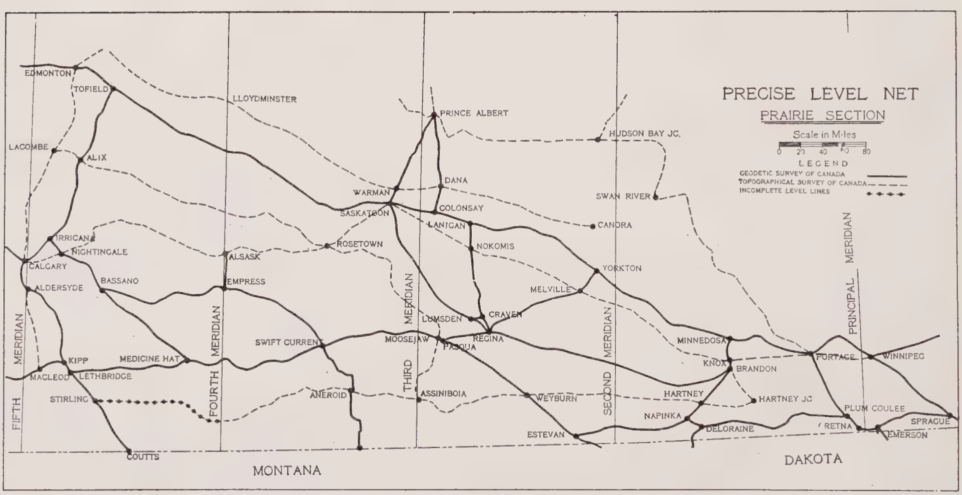
Adjustment of Triangulation and Level Nets.—The differential method of adjustment, mentioned above, has been very successfully used in the adjustment of the triangulation net on the lower St. Lawrence river and gulf. This net extends from a point about 80 miles below Quebec to Anticosti island, a distance of some 300 miles. The field work has covered about five seasons. The work of the first three seasons was adjusted as a distinct unit, as was that of the last two seasons, by ignoring the lines connecting the two units. By the method of adjustment used the two units were joined and all the work of both retained, the addition of the second unit providing extra corrections to those first determined. By this means the adjustments could be kept up to date with no lost effort and final results could be more quickly made available.

The adjustment of the precise level net has been treated in a similar manner. The first adjustment of the Canadian precise level net was based on the values of mean sea-level obtained from the tidal stations at Halifax, Yarmouth and Father Point on the Atlantic coast. This adjustment gave certain corrections to the elevations over the whole country which had been obtained from the instrumental or field results. The inclusion in the adjustment of the Pacific Coast tidal stations at Vancouver and Prince Rupert, altered the first adjustment by providing additive corrections to the elevations, and showed the influence of the Pacific Coast tidal stations on elevations carried through from and based on the Atlantic. Knowledge of the magnitude and effect of this influence was of the greatest value and was by this method of adjustment easily seen. Similarly the inclusion of a number of connections with the precise level net of the United States will disclose the influence which these points will have on elevations in Canada.

Determination of the Precisions or Probable Accuracy of Various Parts of Triangulation and Level Nets as Advisory for New Field Work.—The question of precisions is one on which there is liable to be a certain amount of confusion. It is to be borne in mind that the precision of any quantity depends upon the number of observations which enter into the make up or complexity of the scheme, and which, by their inter-relationship affect the value of the precisions. Hence precisions may be said to have a " strength "; or, to quote Colonel Sir Charles Close in " The Second Geodetic Levelling of England and Wales," a formula " may lead to quite erroneous estimates of the probable error if the number of observations is small. This introduces into a set of observations a characteristic which we may call the strength of the probable error. It is easy to see that in general the relative strength of two probable errors depends upon the relative number of errors available, and that the one with the greater number has the stronger probable error."

That a probable error may present very little strength, again quoting Colonel Sir Charles Close, " is seen by a case of relevelling a line by backward and forward observations. Hence, if v is the discrepancy and hence $\frac{v}{2}$ the


LEVEL NET
OF
EASTERN CANADA
Father Point
Edmundston
Chatham
Moncton
Truro
Halifax
Windsor
Middleton
Yarmouth
McAdam Jct.
Brunswick Jct.
St. Stephen
Quebec
Lake Henry
Whitney
Parry Sound
Coldwater
Prescott
Brockville
Sarnia
Detroit
Windsor
Chatham
Bridgeburg
LAKE ERIE
LAKE ONTARIO
Levelling by Geodetic Survey of Canada shown by full black lines
Levelling by U S Coast and Geodetic Survey shown by dotted black lines
Tidal Survey Bench Marks indicated thus
Points where Canadian and American levelling join indicated thus


PRECISE LEVEL NET
PRAIRIE SECTION
Scale in Miles
0 20 40 60 80
LEGEND
GEODETIC SURVEY OF CANADA
TOPOGRAPHICAL SURVEY OF CANADA
INCOMPLETE LEVEL LINES
EDMONTON
TOFIELD
LLOYDMINSTER
PRINCE ALBERT
HUDSON BAY JC.
LACOMBE
ALIX
DANA
WARMAN
SASKATOON
COLONSAY
LANIGAN
SWAN RIVER
CANORA
IRRICANA
NIGHTINGALE
CALGARY
ALDERSYDE
BASSANO
ALSASK
ROSETOWN
EMPRESS
NOKOMIS
YORKTON
MELVILLE
LUMSDEN
CRAVEN
REGINA
PASQUA
MOOSEJAW
SWIFT CURRENT
MINNEDOSA
KNOX
BRANDON
PORTAGE
WINNIPEG
KIPP
MEDICINE HAT
MACLEOD
LETHBRIDGE
STIRLING
ANEROID
ASSINIBOIA
WEYBURN
HARTNEY
HARTNEY JC
NAPINKA
DELORAINE
ESTEVAN
PLUM COULEE
RETNA
SPRAGUE
EMERSON
COUTTS
MONTANA
DAKOTA
FIFTH MERIDIAN
FOURTH MERIDIAN
THIRD MERIDIAN
SECOND MERIDIAN
PRINCIPAL MERIDIAN

discrepancy from the mean, the probable error of the mean possesses very little strength, and the application of Gauss' distribution law to a small number of errors is quite unjustified."

The above conclusions show the danger of making adjustments by small figures or nets in place of by larger figures or nets. As no adjustment gives absolutely true values, and as a small number of observations must give results which have " little strength," all possible care should be taken to adjust as many observations as possible, so as to increase the strength.

The use of the method of differential adjustment enables one to determine whether or not the previous old adjustment really has the required strength. If it is sufficiently sound it should be able to withstand the challenge of the new observations, able to include them and not be materially disturbed thereby.

It may be noted that all the adjustments and probable errors which have been determined by the Geodetic Survey have always been classified according to the amount of strength they possess. Only in this way can hasty and premature pronouncements be avoided, and only so can we prevent undue reliance being placed upon results which should be called only preliminary in their adjustment, and which should be strengthened by being incorporated in a larger adjustment.

LIST OF PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

Publication No. 1—Precise Levelling—Certain lines in Quebec, Ontario and British Columbia.

Publication No. 2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.

Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.

Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.

Publication No. 5—Field instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation.

Appendix No. 1 of Publication No. 5—Instructions to Lightkeepers on Primary Triangulation.

*Publication No. 6—Precise Levelling—Certain Lines in Manitoba and Saskatchewan.

Publication No. 7—Geodetic Position Evaluation.

Publication No. 8—Field Instructions for Precise Levelling.

Publication No. 9—The Making of Topographical Maps of Cities and Towns, the First Step in Town Planning.

Publication No. 10—Instructions for Building Triangulation Towers.

Instructions to Lightkeepers; Use of Electric Signal Lamps being Appendix No. 4 to Publication No. 5.

The Geodetic Survey of Canada; Operations, April 1, 1912, to March 31, 1922—Publications of the International Geodetic and Geophysical Union, 1922.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1921.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1922.

Precise Levelling Bulletins

In addition to the regular publications, enumerated above, a series of Precise Levelling Bulletins is in course of preparation and will be available for distribution in 1923-24. These are in pamphlet form and contain results for all the precise level lines run by this Survey in the western provinces and Northern Ontario. The Bulletins are designed solely

* Superseded by Precise Levelling Bulletins.

to give available results in concise form to the engineering public and hence the explanatory matter has been reduced to a minimum. Each pamphlet contains a group of from two to five lines of precise levelling, the contents being as follows:—

Bulletin A—
Vancouver, B.C., and adjacent district—as far east as Mission, Matsqui and Huntingdon.

Bulletin B—
Abbotsford to Resplendent, B.C.
Spence Bridge to Brodie, B.C.
Mission to Hope, B.C.

Bulletin C—
Saskatoon, Sask., to Prince George, B.C.
Prince Rupert to Prince George, B.C.

Bulletin D—
Calgary, Alta., to Kamloops, B.C.
Revelstoke to Arrowhead, B.C.
Sicamous to Okanagan Landing, B.C.

Bulletin E—
Kipp, Alta., to Golden, B.C.
Bull River to Kootenay Landing, B.C.

Bulletin F—
Calgary to Lethbridge, Alta.
Calgary to Tofield, Alta.
Camrose to Wetaskiwin, Alta.

Bulletin G—
Moose Jaw, Sask., to Coutts, Alta.
Swift Current, Sask., to International Boundary.

Bulletin H—
Irricana to Medicine Hat, Alta.
Bassano, Alta., to Swift Current, Sask.
Empress to Compeer, Alta.
Kerrobert to Unity, Sask.

Bulletin I—
Stephen, Minn., to Regina, Sask.
Regina to Prince Albert, Sask.

Bulletin J—
Napinka to Neepawa, Man.
Minnedosa, Man., to Regina, Sask.
Yorkton to Saskatoon, Sask.
Colonsay to Prince Albert, Sask.
Lanigan, Sask., to Brandon, Man.

Bulletin K
Emerson, Man., to Port Arthur, Ont.
Sprague to Neepawa, Man.
Portage-la-Prairie to Plum Coulee, Man.

Bulletin L—
Winnipeg, Man., to Kenora, Ont.
Winnipeg to Victoria Beach, Man.

Bulletin M—
Rennie, Man., to Armstrong, Ont.
Superior Junction to Rowan, Ont.

Bulletin N—
Sudbury to Cochrane, Ont.
Armstrong to Cochrane, Ont.

Copies of the above publications may be obtained by applying to the Director of the Geodetic Survey of Canada.

Respectfully submitted,

NOEL OGILVIE,
Director.

To W. W. Cory, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

INDEX

Department of the Interior
GEODETIC SURVEY OF CANADA
MAP SHOWING
PROGRESS OF TRIANGULATION
AND
PRECISE LEVELLING
TO MARCH 31, 1923
NOEL OGILVIE, DIRECTOR
Scale, 100 miles to one inch
LEGEND
TRIANGULATION COMPLETED
TRIANGULATION BEGUN
PRECISE LEVELLING
HUDSON BAY
NORTHWEST TERRITORIES
DISTRICT OF MACKENZIE
DISTRICT OF KEEWATIN
YUKON
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
LABRADOR
NEW BRUNSWICK
NOVA SCOTIA
NEWFOUNDLAND
GULF OF ST LAWRENCE
ATLANTIC OCEAN
PACIFIC OCEAN
Victoria Island
James Bay
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
ONTARIO
WASHINGTON
NORTH DAKOTA
SOUTH DAKOTA
QUEEN CHARLOTTE ISLANDS
GREAT BEAR LAKE
GREAT SLAVE LAKE